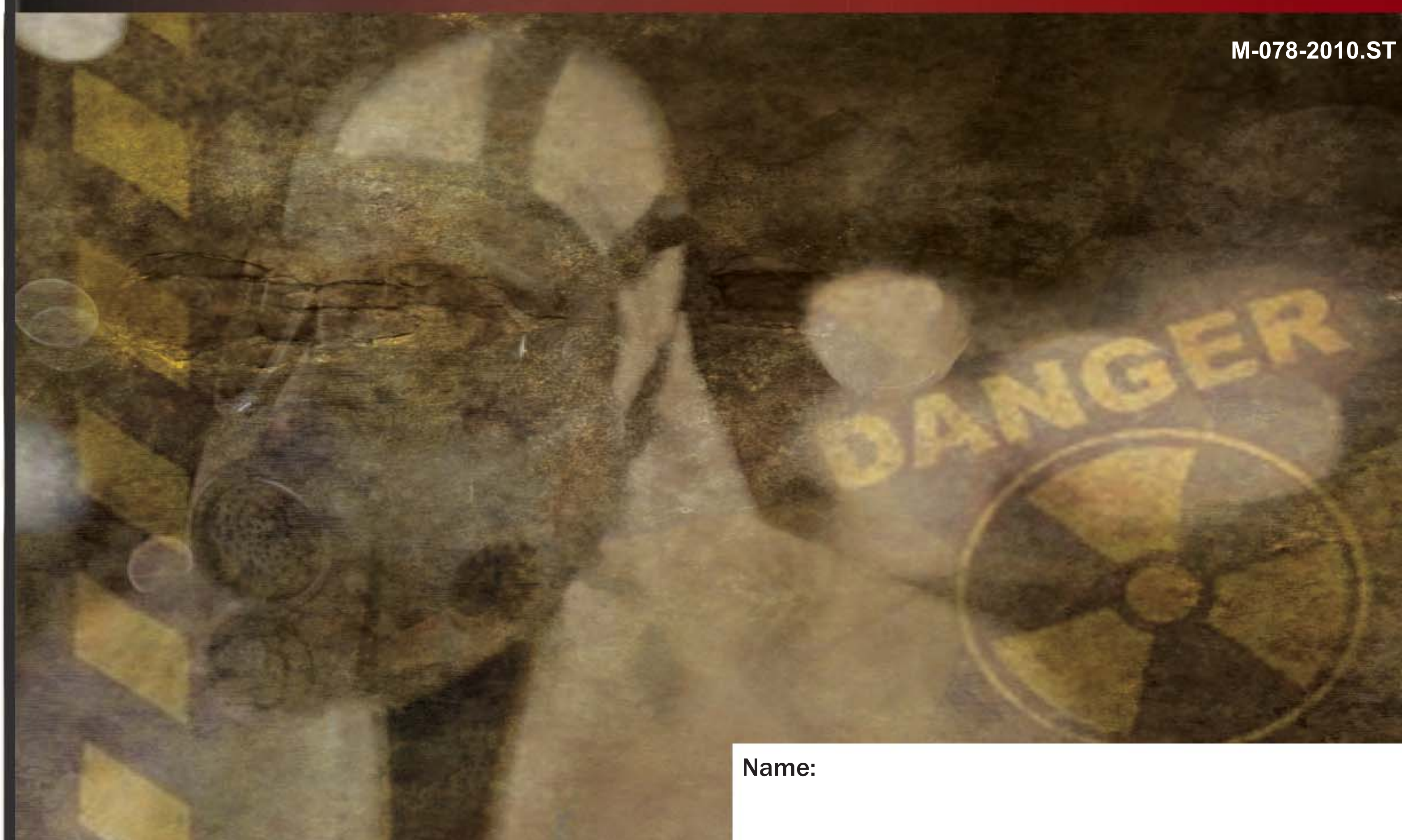
IUOE National Training Fund
National HAZMAT Program

Radiological Worker II Course

Student Manual

M-078-2010.ST



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- It is not the intent of the content developers to provide compliance-based training in this presentation, the intent is to address hazard awareness in the hazardous waste operations and emergency response (HAZWOPER) industry, and to recognize the overlapping hazards present in many construction workplaces.

- It should NOT be assumed that the suggestions, comments, or recommendations contained herein constitute a thorough review of the applicable standards, nor should discussion of "issues" or "concerns" be construed as a prioritization of hazards or possible controls. Where opinions ("best practices") have been expressed, it is important to remember that safety issues general and HAZWOPER jobsites specifically will require a great deal of site- or hazard-specificity – a "one size fits all" approach is not recommended, nor will it likely be very effective.

This training program was developed for the IUOE National Training Fund by

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- Bernard Mizula: Curriculum development
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- Mark Jackson: Grammar review
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- International Brotherhood of Teamsters: Program material contributions

To: Users of IUOE National Training Fund Programs

The IUOE National Training Fund -- National HAZMAT Program offers a broad spectrum of safety and health training, as well as training support to other users of the National HAZMAT Program's resources. The National HAZMAT Program has available, at no cost, the following:

- Direct training for IUOE Local Union members and other appropriate groups conducted at the Local Union, at an employer's site, or other appropriate locations
- Training materials, including personal protective equipment, and other types of equipment for National HAZMAT Program Master Instructors' HAZWOPER and other safety and health related classes
- New instructor mentoring for HAZWOPER and other safety and health related classes
- Safety and health regulations and standards interpretation assistance
- Technical safety and health, emergency/disaster response, and energy security and restoration assistance
- Training data information from the National training database for Local Union members and others who have completed training through the National HAZMAT Program
- Expertise to provide best practices and information sharing, develop scenarios, and conduct exercises to prepare all stakeholders to protect and restore critical infrastructure should an event, manmade or natural, occur
- Training information on HAZWOPER, OSHA, emergency/disaster response, and other safety and health classes held at other IUOE Local Unions nationwide

Inquiries regarding the services the IUOE National Training Fund -- National HAZMAT Program have to offer can be directed to Barbara McCabe at 1293 Airport Road, Beaver, WV 25813, called in at (304) 253-8674, faxed to (304) 253-7758, or emailed to hazmat@iuoehazmat.org. Forms requesting classes and materials can also be submitted via the Internet at www.iuoehazmat.org.

The IUOE National Training Fund encourages all workers to take advantage of the National HAZMAT Program's services to assist you to be employable, competitive, and safe in the workplace.

Sincerely,

Jeffrey R. Vincent
Executive Director,
IUOE National Training Fund

Table of Contents

Module 1: Course Introduction


Figure 1.0: IUOE trainee gets ready to operate a dozer while dressed in level C PPE, Courtesy LU825.

Objectives

At the end of this module, you will have an understanding of the following:

- Goal of this manual and course
- Course overview
- Regulations protecting Department Of Energy (DOE) radiological workers
- Regulations protecting workers handling radiological materials on non-DOE sites
- DOE requirements for radiological worker training
- Introduction to the IUOE National Training Fund's National Hazmat Program

Purpose of the module

This module provides a course overview so that you, as the participant, will know what to expect in this course. The module presents a basic introduction to the regulations and training requirements surrounding radiological work on DOE sites. This module also provides a review of the regulations protecting radiological workers on DOE and non-DOE sites. An overview of the IUOE National Training Fund-National Hazmat Program is also presented.

Activity 1.1: Sharing your thoughts on health, safety and radiation

Time for activity: 15 minutes (10 for group work and 5 for report back)

Objective: The goal of this activity is to share and discuss your experience and thoughts with your fellow classmates and instructors regarding the relationship between occupational health and safety and radiological work.

Task: In your groups, work together to discuss and answer the following questions. Select a spokesperson to present your group's answers to the class. Try to come to a mutual answer for each of the questions.

1. True or False: There are many laws from different government agencies that help to adequately protect me when I work around or with radiation. Explain your answer.

2. Agree or Disagree: Radiological work is risky work but taking risks is part of the job and the compensation I receive outweighs the risks. Explain your answer.

3. Agree or Disagree: Radiation is harmful to human health. It is by far the greatest hazard that will be faced during radiological work.

4. Name five common places, procedures or products (example: smoke detectors) that contain radiation or radiological sources.

5. Agree or Disagree: Radiation is easy to detect and may be recognized without monitoring equipment. Explain your answer.

Objective 1: The goal of this manual and course

> The goal of this training program is to impart a high level of knowledge and skills in radiological fundamentals to the radiological workers at all DOE facilities.

This manual was prepared by the IUOE National Training Fund-National Hazmat Program for use in Radiological Worker I and Radiological Worker II courses to prepare workers for work in radiological controlled areas of sites operated by the DOE. These materials closely follow the DOE handbook on Radiological Worker II (RWII) training (DOE-HDBK-1130-2007, December 2007). This course satisfies 10 CFR 835-Subpart J, "Radiation Safety Training", recommendations identified in chapter 14, Radiation Safety Training, of DOE Implementation Guide G441.1 (extended by G441.2) and the DOE Radiological Control Manual (RCM).

The DOE takes worker health and safety and training seriously

DOE Directive N 441.1 (extended by N 441.2) states:

(6)(c)(1) Radiation safety training for ... radiological workers... shall utilize those portions of the standardized core training materials published by DOE that are relevant to facility hazards and operations, augmented as necessary by site-specific materials. Documentation of satisfactory completion of the entire DOE standardized core course(s) shall be accepted by all DOE activities.

(6)(c)(2) Training requirements commensurate with the hazard within a posted area shall be completed prior to permitting an individual unescorted access to that area.

In compliance with the directive, this manual and course cover all of the standardized core academics and the appropriate practical factors covering training requirements for RW I and RW II. Upon completion of this training course, the participant will have the knowledge and skills to work more safely in radiological controlled areas.

Objective 2: Course overview

This manual includes 12 modules and a test. The manual is designed to satisfy the requirements of RW I and II training. The practical factors exercises may be different for RW I and RW II.

Module 1-Course Introduction
Module 2- Radiological Fundamentals
Module 3-Biological Effects of Radiation
Module 4- Radiation Dose Limits
Module 5-ALARA Programs
Module 6- Personnel Monitoring Programs
Module 7- Radiological Access Controls and Postings
Module 8- HR/VHR Area Training
Module 9- Radioactive Contamination Control
Module 10- Radiological Emergencies
Module 11-Written Test
Module 12- Practical Factors (covering RW 1 and RW2)

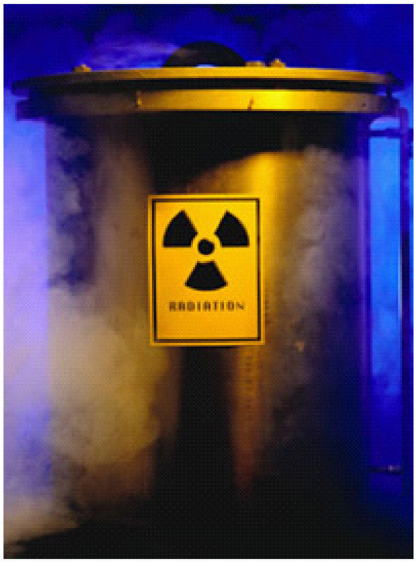


Figure 1.1 Training will help prepare you for working with radiological materials.

To be trained as a radiological worker, the participant must complete this course, pass a 50-question written exam and a practical evaluation. Successful completion of the written examination (minimum score of 80%) must be achieved. The written exam is based on the objectives in the theory portion of the course (Modules 2-8). A participant must pass the written exam in order to take the practical factors evaluation. Successful completion of the practical factors evaluation (minimum score of 80%) must also be achieved. The practical factors evaluation includes entry into a simulated controlled work environment. This evaluation is based on the application of the theory portions of this course.

If a participant scores lower than 80% on either the written test or the practical factors evaluation, they must retake the test in accordance with the particular DOE site-specific retraining policy or the IUOE National Training Fund-National Hazmat Program retraining policy.

Objective 3: Regulations protecting Department Of Energy (DOE) radiological workers

What is the difference between radiation protection standards on DOE sites and non-DOE sites?

It is the policy of the DOE to conduct its radiological operations in a manner that ensures the health and safety of all its employees, contractors, and the general public.

Activity 1.1: Have you heard of DOE and OSHA?

Write down what you know about these two Federal agencies and what they do.

The DOE is the governing body when it comes to radiation protection on DOE sites. Worker protection is covered under 10 CFR 835. Recommendations may be found under DOE Implementation Guide 441.1 (441.2 extended). The DOE also has established procedures outlined in the DOE Radiological Control Manual (RCM) 1994.

Objective 4: Regulations protecting workers handling radiological materials on non-DOE sites

For sites dealing with radiological material that is not on DOE sites, there is an Occupational Health and Safety Administration (OSHA) standard for radiation. It is 29 CFR 1910.1096, "Ionizing Radiation". There is an OSHA construction standard for radiation, 1926.53, but it is not nearly as specific as for the general industry. Both DOE and OSHA and their pertinent requirements will be discussed in greater detail throughout the course.

It is important to understand that there are regulations that employers must follow to ensure your well being as a worker who works with or around radiological material.

Objective 5: DOE requirements for radiological worker training

The DOE has specific training standards for different types of recognized workers on DOE sites. The following requirements are stated in the DOE RCM Chapter 6, Part 3.

DOE RCM Article 631 lists the following training requirements:

1.Radiological Worker I training is required for unescorted entry into areas as stated in DOE RCM; Table 6-1 (Table 1.1 of this manual).

2. Radiological Worker II training is required for unescorted entry into areas as stated in DOE RCM Table 6-1(Table 1.1 of this manual). Additional training is required for special job functions with radiological consequences per Article 634.1 of the DOE RCM.

3. A worker may waive this course and fulfill the Radiological Worker I or II standardized core knowledge requirements by passing a comprehensive examination. If unsuccessful in the first attempt at the examination, the worker shall complete the entire standardized core Radiological Worker I or II training. Attempts to waive the training do not apply to the site-specific portions of the course.

4. Radiological Worker I training is not a prerequisite for Radiological Worker II training.

5. Radiological Worker I and Radiological Worker II training are self-contained courses. Radiological Worker II training includes all of the requirements of Radiological Worker I training and expands on the topic of hands-on work with radioactive materials. Radiological Worker II training prepares the worker to deal with higher levels of radiation and radioactive contamination.

Excavated Soil Surveyed for Radioactive Contamination. Courtesy DOE. Because operators handle soil contaminated by radiological materials, the RW II course is required.

Table 1.1 Summary of Radiological Worker Entry Training Requirements: Adopted from DOE RCM Table 6.1		
Areas	Rad Worker I	Rad Worker II
Entry into Radiological Buffer Areas	Yes	Yes
Entry into Radiation Areas	Yes	Yes
Entry into High or Very High Radiation Areas*	No **	Yes
Entry into Contamination Areas and High Contamination Areas	No	Yes
Entry into Soil Contamination Areas (to perform work that disturbs soil)	No	Yes
Entry into Airborne Radioactivity Areas*	No	Yes **
*Entry requirements further restricted by Article 334		
**Entry prohibited unless trained in accordance with Article 632.5		
***Requires respiratory protection qualification as stated in Article 531		

Radiological Worker I (RW I)

This training is for radiological workers whose job assignments require unescorted access to Radiological Buffer Areas, Radioactive Materials Areas and Radiation Areas. RW I training is also suggested for unescorted entry into Radioactive Material Areas containing either sealed radioactive sources or radioactive material labeled in accordance with 10 CFR 835. The High/Very High Radiation (HR/VHR) Area module may be added to the Radiological Worker I course to grant the personnel unescorted entry into High Radiation Areas where contamination is not a concern. It is suggested that RW I tasks be limited to inspections, tours, and activities that involve work on non-radiological systems.

RW I training includes the core training requirements (modules 2-7 and 10) plus applicable practical factors relating to the assumed work. Unescorted worker access to High or Very High Radiation Areas is permitted upon successful completion of Radiological Worker I training and High/Very High Radiation Area training (module 8). Completion of this training does not authorize access to Contamination, High Contamination, Soil Contamination, or Airborne Radioactivity Areas.

RW I training alone does not prepare the worker to work around high radiation levels or with contaminated materials.

Expected time to complete the standardized core course and site-specific Radiological Worker I training is approximately 8 hours. Course length will vary depending on the amount of site-specific material.

Radiological Worker II (RW II)

This course consists of the core academics (module 2-7 and 10), the High/Very High Radiation Area module (module 8), the Contamination Control module (module 9), plus the appropriate practical factors module. This training is recommended for the radiological worker whose job assignments involve unescorted entry into High Radiation Areas, Contamination Areas, High Contamination Areas, and Airborne Radioactivity Areas. Further, workers who have potential contact with hot particles or use glove boxes with high contamination levels should complete RW II training.

RW II training prepares the worker to work around higher radiation levels and with contaminated materials normally associated with radiological facilities/activities.

Expected time to complete the standardized core and site-specific Radiological Worker II training is approximately 24 hours. Course length will vary depending on the amount of site-specific material.

Practical factors training

Radiological Worker I and II training shall encompass a number of different, work-related, site-specific practical factors including some or all of the following:

- Donning protective clothing
- Entering a simulated Radiological Buffer Area, Contamination Area and High Radiation Area to perform a task
- Anticipated response to simulated abnormal situations
- Anticipated response to simulated alarms or faulty radiological control equipment
- Removing protective clothing and equipment and subsequently exiting the simulated area
- Frisking personnel for contamination
- Verification of instrument response and source check

Specialized Radiological Worker Training Requirements

1. Specialized Radiological Worker training shall be completed for non-routine operations or work in areas with changing radiological conditions. This training is in addition to Radiological Worker II training and is required for personnel planning, preparing and performing jobs that have the potential for high radiological consequences. Such jobs may involve special containment devices, the use of mockups and As Low As Reasonably Achieveable (ALARA) considerations.

2. Additional training for employees at specialized facilities, such as accelerators and laboratories, may be required.

Site-specific and job specific training

Depending on the type of work and radiological material, additional site-specific training may be required. Check with you supervisor or site radiological worker training program administrator. This course also does not satisfy certain job or duty specific health and safety requirements such as respiratory training, confined space entry training, etc. See your supervisor if you have any questions as to the additional training that may be required for you to safely perform your job.

Refresher Training

Refresher training programs for RW I and II training may be implemented in the alternate year when full retraining is not completed or in response to observations or indications of poor radiological performance. Refresher training is intended to maintain and enhance the proficiency of the worker. The refresher training for RW I and II training should be documented.

Objective 6: Introduction to the IUOE National Training Funds National Hazmat Program

The IUOE National Training Fund National HAZMAT Program provides HAZWOPER and OSHA Train-the-Trainer classes to allow each IUOE local union the ability to train and certify its members. This peer-training method gives IUOE members a more competitive advantage in the workplace and provides the training they need to perform their jobs in a safe manner.

Operating engineers don PPE in preparation of a training exercise. Courtesy IUOE.

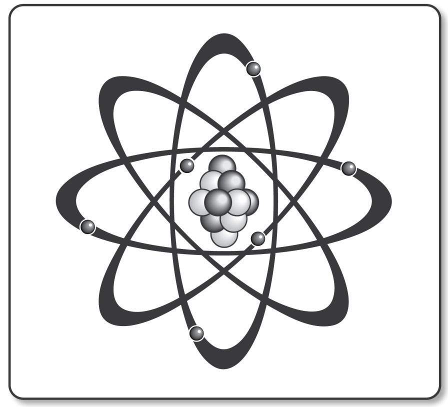
Some of the training courses offered include: asbestos abatement supervisor, asbestos inspector, confined space entry/rescue, industrial hygene, fall protection, radiological worker II, American Red Cross CPR, construction and general industry, trenching/shoring/excavation, and disaster site worker.

In addition to the train-the-trainer classes conducted at the training center in West Virginia, the IUOE National Training Fund National HAZMAT Program provides IUOE local unions with a wide variety of other training classes and training materials. For more information, visit http://www.iuoehazmat.org.

Notes:

Module 2: Radiological Fundamentals

Objectives



At the end of this module you will be able to:

- List the three basic particles of an atom
- Define radioactive material, radioactivity, radioactive half-life, radioactive contamination and radiation exposure
- Define and contrast ionization and non-ionizing radiation
- Identify the four basic types of ionizing radiation and the following for each type:
  - Physical characteristics
  - Range
  - Shielding
  - Biological hazards
  - Sources at the work site
- Identify the units used to measure radiation
- Convert rem to millirem and millirem to rem

Purpose of the module

This module will discuss several nuclear science topics at a basic level appropriate for the radiological worker. You will be introduced to basic radiological fundamentals and terms that are common in the DOE complex and in other radiological work.

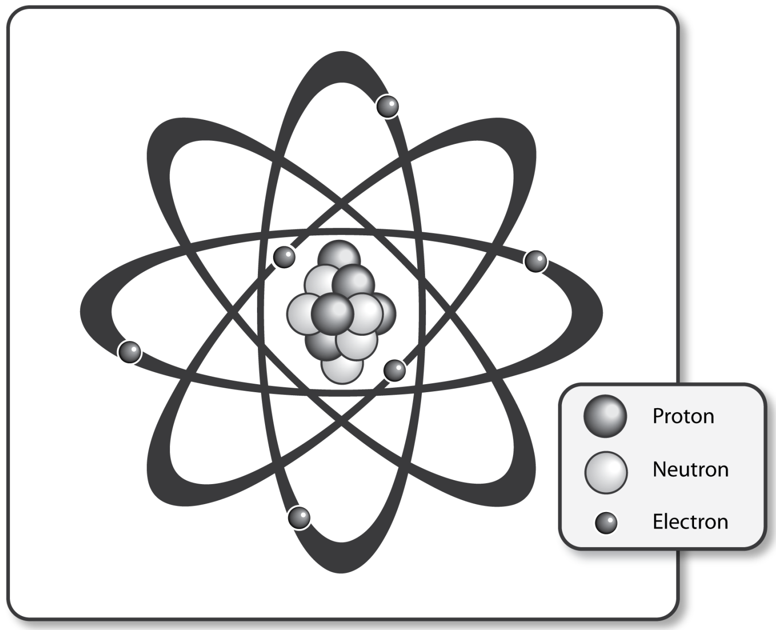
This module provides an introduction to radiological fundamentals. What are atoms made of? What is radiation? Are there different types of radiation? These questions and more will be explored as you progress through this module. Given various radiological concepts, you will be able to define the fundamentals of radiation, radioactive material, and radioactive contamination in accordance with this manual and course.

These concepts are necessary for the worker to understand the nature of radiation and its potential effects on human health. After learning the fundamentals of radiation, radioactive material, and radioactive contamination, the worker will build upon the basics to gain more extensive knowledge in subsequent modules of the course.

Objective 1: List the three basic particles of an atom

The atom

All common materials, whether they are gas, liquid, or solid, are made of atoms. Atoms are the smallest, most basic particles of matter that retain the properties of an element (such as carbon, lead, and helium; see below for more information on elements).



A representation of an atom depicting 1.) the nucleus consisting of protons and neutrons and 2.) electrons orbiting around the nucleus.

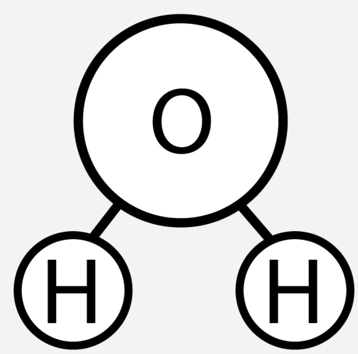
Atoms are made of two parts: the nucleus and the orbital shell surrounding the nucleus. Further, the atom can be described as having three basic particles. The three basic particles of the atom are protons and neutrons located in the nucleus, and electrons that are located in the orbital shell.

There are 118 different kinds of atoms, which are known as the chemical elements. 115 are known and three are currently theoretical. Some are naturally occurring and some are manmade. Examples of chemical elements are: carbon, lead and helium. For more on the 118 elements, see the periodic table of elements on the next page. This table lists elements in categories and assigns specific numbers to each element based on its parts (as we shall learn later). Also, each element is given a symbol. For example, the elemental symbol for oxygen is O, and the symbol for carbon is C. The periodic table of elements is a very interesting arrangement of the elements—it provides a wealth of information about each element. A thorough understanding of the table of elements is beyond the scope of this class but it is important that you know what it is. It is also important that you have a basic understanding of what the table is used for.

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra		104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo
			57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
			89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

What do atoms do?

Molecular Structure of Water (H_2O)



Atoms of the same element or different elements can combine to form molecules or compounds. Take the example of water—it is a combination of two atoms of hydrogen and one atom of oxygen. There are over 100,000 different chemical compounds in use today with roughly 500 new ones created each year!

Basic particles of the atom

To get a better understanding of atoms and how atoms are related to radiation, let's investigate the composition of an atom.

The atom's nucleus

The nucleus is the core of the atom and is composed of two types of particles, protons which are positively charged, and neutrons are neutral (or zero charge). Refer to the graphic representation of the atom on page 2-2.

The atom's electrons

The third part of the atom is the electron. Electrons are negatively charged. There can be different numbers of electrons for the same atom—this will determine the atom's chemical properties. Electrons are located outside of the atom's nucleus; they orbit the nucleus at different distances from the nucleus. This area surrounding the nucleus is often called the atom's "orbital shell" and may contain many different layers or "orbits." Just imagine the planets orbiting the sun. Electrons are held in orbit around the nucleus by their electromagnetic attraction to the positively charged protons. The farther an electron is from the nucleus, the less energy is required to free it from the atom. We will see how this phenomenon relates to worker safety later. Refer to the graphic representation of the atom on page 2-2.

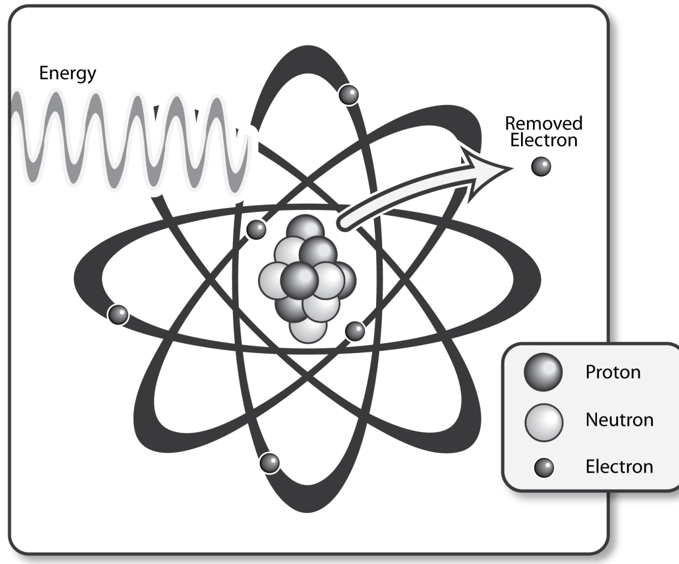
Table 2.1 below summarizes the parts of an atom.

Table 2.1: Basic Particles of an Atom

Particle	Charge	Other Properties
Proton	+	Located in the nucleus. The number of protons determines element.
Neutron	0 (neutral)	Located in the nucleus. The number of neutrons determines isotope.
Electron	-1	Orbits around nucleus. Number of electrons determines chemical properties.

In general, each atom has an equal number of protons and electrons so the atom is an electrically neutral unit.

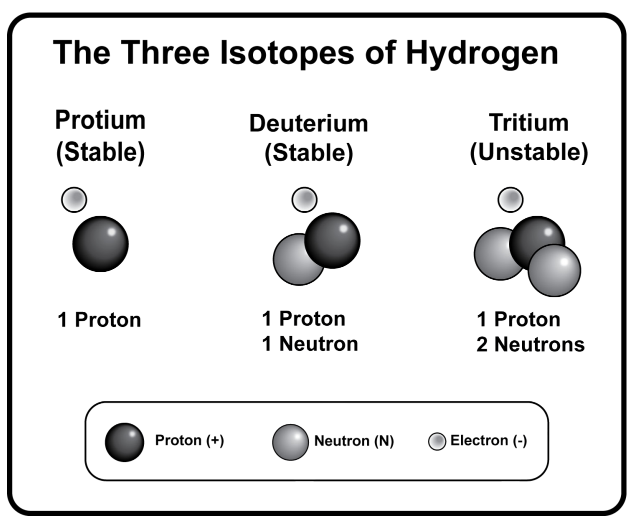
What makes an element an element?



An element is a substance made up of atoms bearing an identical number of protons in each nucleus. If atoms have the same number of protons, but a different number of neutrons, they are called isotopes of the element. Some elements are known to have many isotopes, and some have only a few—for example tin has 37 known isotopes but hydrogen only has 3. Isotopes retain the same chemical properties of the element, but may exhibit different nuclear properties, such as nuclear decay. The number of protons determines the element; so if the number of protons changes, the element changes.

Atoms of the same element have the same number of protons but can have a different number of neutrons. Let's look at the three isotpoes of hydrogen as an examle. The three isotopes of hydrogen are: hydrogen, with one proton; deuterium, with one proton and one neutron; and tritium, with one proton and two neutrons.

Again, the number of neutrons determines the isotope of the element. Isotopes have the same chemical properties but can have very different nuclear properties (how the atom behaves). The diagram to the left illustrates the three isotopes of hydrogen.



Charge of the atom

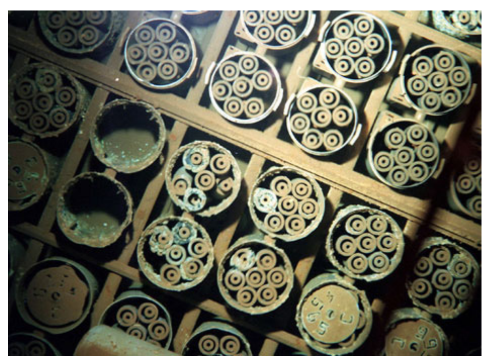
The number of electrons and protons determines the overall electrical charge of the atom. The term "ion" is used to define an atom or group of atoms that have a positive or negative electrical charge. The following are three types of possible charges on atoms:

- No charge (neutral) – If the number of electrons equals the number of protons, the atom is electrically neutral and does not have an electrical charge
- Positive charge (+) – More protons than electrons
- Negative charge (-) – More electrons than protons

Objective 2: Define radioactive material, radioactivity, radioactive half-life, and radioactive contamination

Radioactive Material

Any material containing radioactive atoms is either called "radioactive material" or a "radioactive source." These sources can be identified because of the characteristic radiation energy they emit. This emitted energy has the potential to harm workers. That is why, as we will see later, we must institute control techniques to protect radiological workers. However, we are around radioactive materials in our daily lives, even if we are not radiological workers.

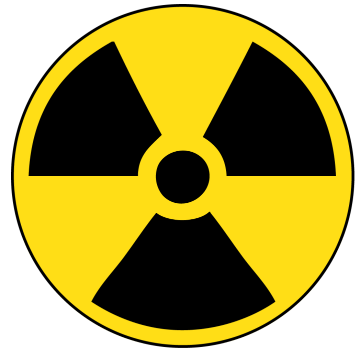


Uncapped fuel stored underwater in K-East Basin, DOE Hanford.

Atom stability

Only certain combinations of neutrons and protons result in stable atoms. If there are too many or too few neutrons for a given number of protons, the resulting nucleus will have too much energy. This type of atom will not be stable. The unstable atom will try to become stable by giving off excess energy in the form of particles or waves (radiation). These unstable atoms are also known as radioactive atoms.

Radioactivity



The radiological trefoil is used to communicate radioactive areas.

Radioactivity is the property of unstable atoms to emit radiation - that is, particles, electromagnetic-wave energy, or both spontaneously. When radioactive (or unstable) atoms adjust, it is called “radioactive decay” or “disintegration.” We can measure this phenomenon with the units and equations described below.

Radioactivity is measured by the number of disintegrations the radioactive material undergoes in a certain period of time. Measures of radioactivity use the following units:

- Disintegrations per minute (dpm)
- Disintegrations per second (dps). Also know as the SI unit Becquerel (Bq)
- Curie (Ci)
- Microcurie µCi
- You can convert between the four measurements as follows:

$$1Ci = 2.2 \times 10^{12} dpm$$

$$1Ci = 3.7 \times 10^{10} dpm$$

$$1Ci = 1 \times 10^{6} \mu Ci$$

Radioactive half-life

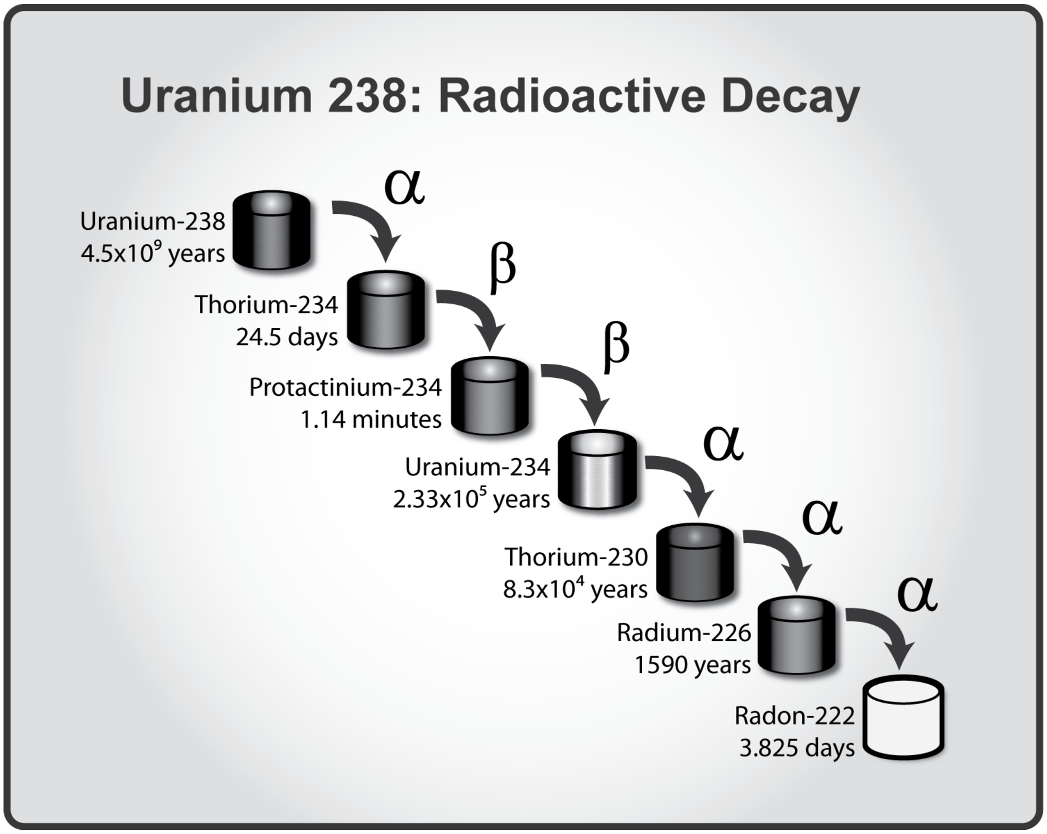
The radioactive half-life of a element and its isotope(s) is the length of time it takes for one half of the radioactive atoms to decay. Every radioactive element and isotope has a specific half-life measured in seconds, days, or even years.

Suppose that you have a certain quantity of uranium. Each uranium nucleus is unstable, but they don't all decay at once. There is a certain probability that a nucleus will decay. If this probability is low, then only a few of the nuclei will decay at a time, and it will take a long time for one-half of the nuclei to decay. The time that it takes for one-half of the nuclei to decay is called the radioactive half-life. After one half-life, one-half of the original atoms have decayed. After a second half-life, one-half of the remaining atoms have decayed, and so on. Different radioactive isotopes have different half-lives, ranging from fractions of a second to billions of years.

When a radioactive nucleus gives off radiation, the atom becomes a different element. For example, uranium-238 has 92 protons. When it gives off an alpha particle it loses two protons and two neutrons. Since the number of protons defines what element an atom is, the uranium atom has become thorium 234, which has 90 protons. Alpha and beta particles will be described later in this module. When an atom gives off an alpha particle, it becomes the element that has two less protons than the original atom. When an atom gives off a beta particle, one of the neutrons changes to a proton. This means that the atom becomes the element that has one more proton than the original atom. Remember that a neutron is a tiny bit bigger than a proton. The difference is about the same as the size of an electron or a beta particle. You might think of a neutron as a combination of a proton and a beta particle. These have different charges, so they cancel each other out, leaving no charge. If you take the beta particle away, then a positively charged proton remains.

Radioactive half-life: if you start with 1 pound of a radioactive element, after one half-life, you will have ½ pound of the element; after two half-lives, ¼ pound, and so on.

If the new atom that forms after alpha or beta emission is not stable, then it too will also give off radiation, and become another element. This process, called a radioactive decay series, continues until a stable atom is formed. The radioactive decay series that begins with uranium-238 and ends with lead-206. The first seven steps in the series are shown in the following diagram:



Radioactive decay

Radioactive decay is the process of radioactive atoms releasing radiation over a period of time. This is done in an attempt to stabilize the atom and to become nonradioactive. Radioactive decay is also known as disintegration.

Radioactive Contamination vs. Radiation Exposure

Radioactive contamination is radioactive material in an unwanted place, such as on your clothing. There are, however, certain places where radioactive material is beneficial. Medical procedures and scientific experiments are examples. Exposure to radiation does not result in contamination of the worker. You can be exposed to radiation without touching the radioactive source. Objects may also be either exposed to radiation or contaminated with a radioactive material. This is important because your tools may become irradiated or contaminated and that can lead to a hazardous situation for you! The following four graphics show relationships between exposure, contamination and internal contamination for Operating Engineers.

This Operating Engineer is standing next to radiological exposure source (the drums).

Here the Operating Engineer is being exposed to radiation without actually contacting the material in the drums.

Here the Operating Engineer is being contaminated by the radioactive soil on the outside of his body.

Here the Operating Engineer is being contaminated by the radioactive soil on the inside of his body because he has breathed in the radioactive soil.

If radioactive contamination gets onto your clothes, intact skin or surfaces, it can be removed through decontamination procedures (See module 9). However, if radioactive contamination gets into your body through inhalation (lungs), digestive system (through eating or mucus) or goes directly into your blood stream (through a cut) it then becomes an internal contamination hazard and may lead to high exposure because you have a radiological source inside your body!

Contamination is measured per unit area or volume and is represented by the following units:

- dpm/100 cm^2
- µCi/ml

Objective 3: Define and contrast ionizing radiation and non-ionizing radiation

Ions

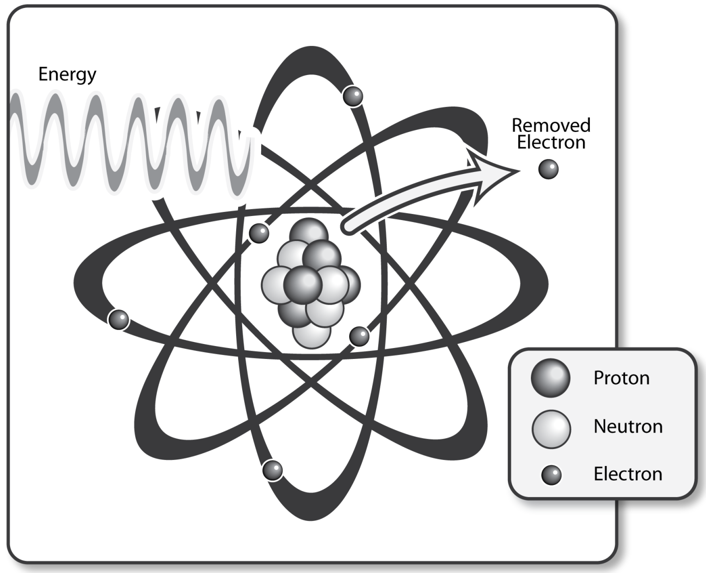
To understand how radiation interacts with its surrounding environment, we must first understand the process of ionization.

The term "ion" is used to define an atom that has an electrical charge. Normally, atoms have an equal number of protons (+ charge) and electrons (- charge) so the total charge is neutral or zero.

An example of ions that will produce water when combined are:

H^{+1}	OH^{-}
Hydrogen ion	**Hydroxide ion**

Ionization



Ionization is the process of removing electrons from neutral atoms. Electrons will be removed from an atom if enough energy is supplied. The remaining atom has a positive (+) charge. Refer to the ion graphic to the right. The ionized atoms may affect chemical processes in human cells thereby damaging living tissue. The ionizations may affect the cell's ability to function normally. The positively charged atom and the negatively charged electron are called an "ion pair." Ionization should not be confused with radiation. Ions (or ion pairs), produced as a result of the interaction of radiation with an atom, allow the detection of radiation.

Ionizing radiation

Ionizing radiation is energy (particles or rays) emitted from radioactive atoms, and some devices, that can cause ionization. Examples of devices that emit ionizing radiation are X-ray machines, accelerators, and fluoroscopes.

Think of an external hazard like the heat you would feel from a fire, you don't have to touch it but it can still burn you. An internal hazard is like the smoke from the fire. You must breath it in, swallow it, or get it in your eyes for it to harm you.

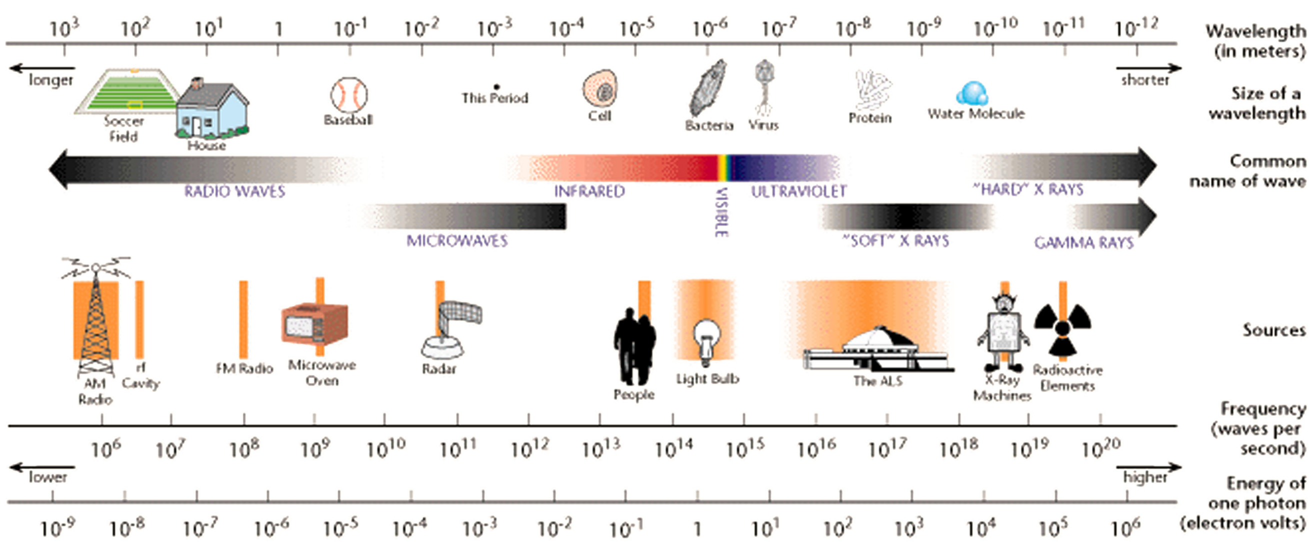
It is important to note that exposure to ionizing radiation, without exposure to radioactive material, will not result in contamination of the worker. Radiation is a type of energy, and contamination is radioactive material that is uncontained and in an unwanted place.

Effects of ionizing radiation on the body

Depending on the type of ionizing radiation, it can be an external hazard to the body or an internal hazard to the body. We will learn more about the biological effects of ionizing radiation in the following sections, as we learn about the different types of ionizing radiation. We will also cover biological effects of radiation in Module 3.

Non-ionizing radiation

Electromagnetic radiation that doesn't have enough energy to ionize an atom is called "non-ionizing radiation." Examples of non-ionizing radiation are radar waves, microwaves, and visible light.



This graphic shows different forms of ionizing and non-ionizing radiation.

Objective 4: Identify the four basic types of ionizing radiation and the characteristics of each type

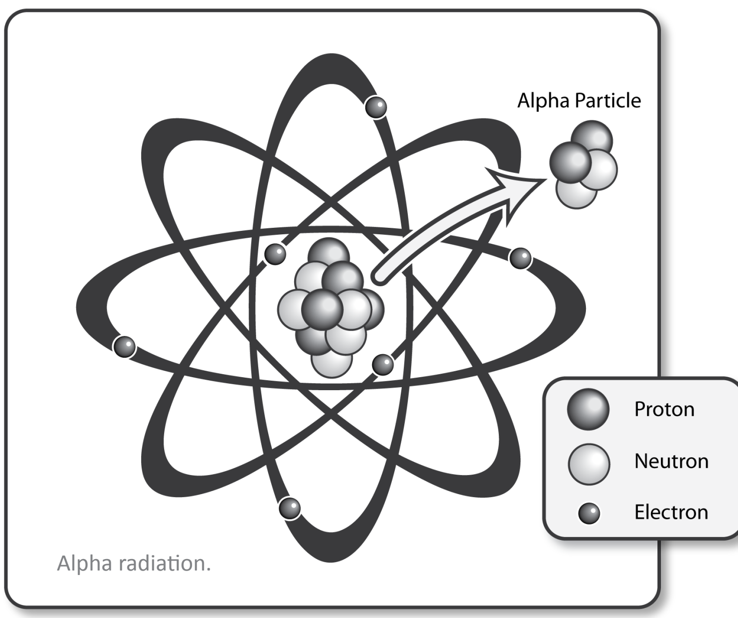
The four basic types of ionizing radiation of concern in the doe and other sites where radiological work is conducted, are alpha particles, beta particles, gamma or X-rays, and neutrons. They all have unique characteristics and can affect workers differently. Also, as we will see, they require different control methods to protect workers from harm.

Alpha particles (α)

ALPHA RADIATION
A particle containing two protons and two neutrons

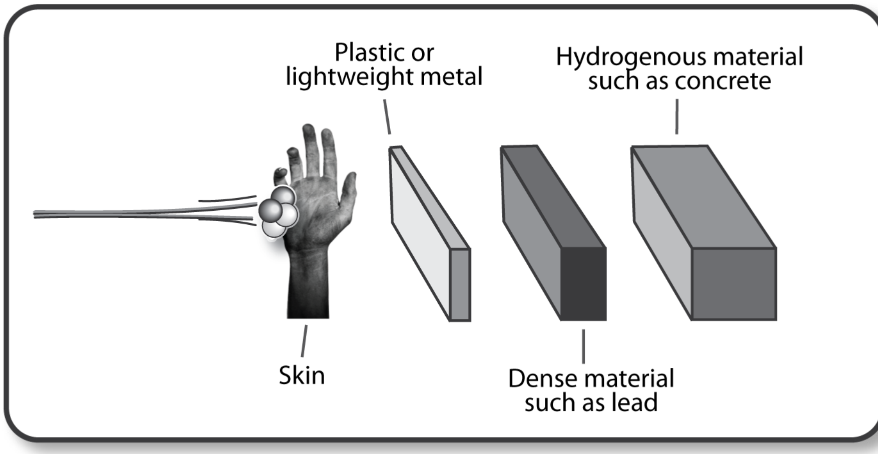
Alpha particles are positively charged particles (having a +2 charge) containing two protons and two neutrons that are emitted from the nuclei of certain heavy atoms, such as uranium, when they decay. Because of its size and charge, an alpha particle only travels a few centimeters in the air. The +2 charge on the alpha particle causes it to strip electrons from nearby atoms as it passes through the material, thereby ionizing these atoms. It can be stopped or shielded using a sheet of paper or the intact skin of a worker.

Although the alpha particle cannot penetrate human skin, it presents an internal hazard. Alpha radiation can be very damaging if its source is inside the body. You must protect your lungs, eyes and GI tract from alpha radiation contamination. You must also take care that it does not enter the body through cut or abraded skin.



Alpha radiation.

List the alpha sources at your site:



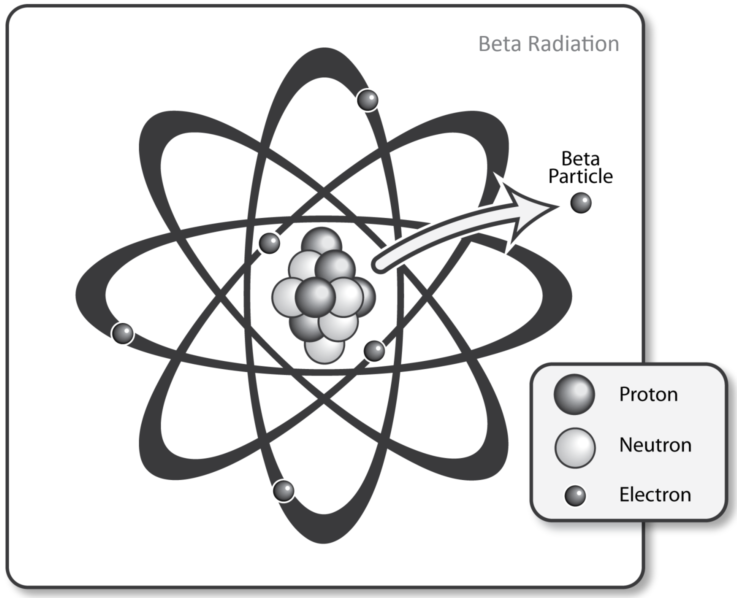
Shielding of alpha radiation. Alpha radiation cannot penetrate skin.

Beta particles (β)

BETA RADIATION
A particle having the mass of an electron

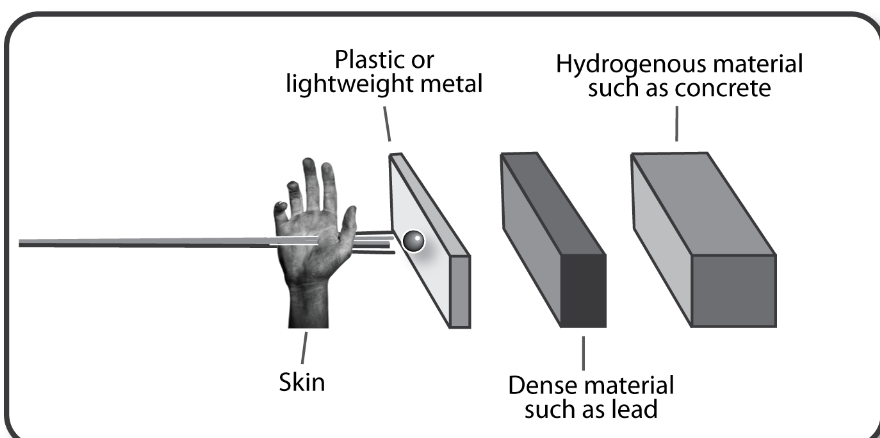
A beta particle is an electron emitted from the nucleus of a radioactive atom. Beta radiation is a stream of high-energy electrons emitted from certain radioactive materials. The beta particles usually have a charge of -1 but may have a charge of +1. If the beta particles have a positive charge, they are called positrons. Both types of beta particles are likely to interact and deposit their energy as they pass through surrounding matter. They have low mass and they can travel as far as 29 feet through the air. Beta radiation causes ionization in surrounding materials by displacing electrons from their orbits.

Beta particles can penetrate the dead layer of skin and affect the live skin tissue, and therefore represent both an internal and external hazard. Large external doses of beta radiation can cause serious injury to the skin and also to the eyes. If ingested or inhaled, the source of the beta radiation is in close contact with body tissue and can deposit energy in a small volume of body tissue.



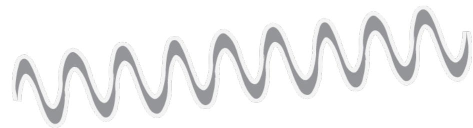
It is also possible to generate beams of high-energy electrons with different devices, but these are not usually termed beta particles. These high-energy electrons can penetrate deep into the body and as a result, require more sophisticated shielding. Shielding materials used for high-energy electrons must be correctly engineered to minimize the phenomenon known as bremsstrahlung radiation. Bremsstrahlung radiation is produced when a high-energy particle penetrates into a dense material producing electromagnetic (X-ray) radiation.

List the beta sources at your site.



Shielding of beta radiation. Beta radiation can penetrate skin, but not typical plastic or light-weight metal.

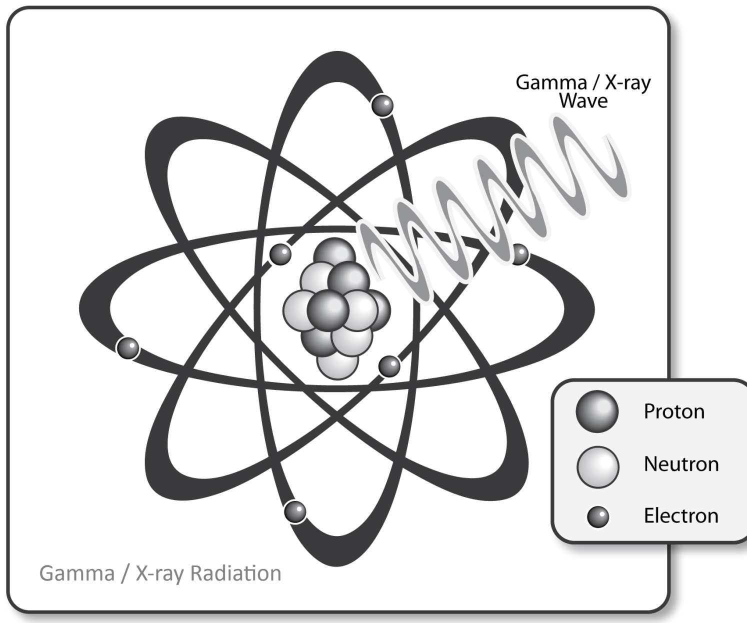
Gamma (γ) and X-rays



GAMMA / X-RAY RADIATION
Electromagnetic wave

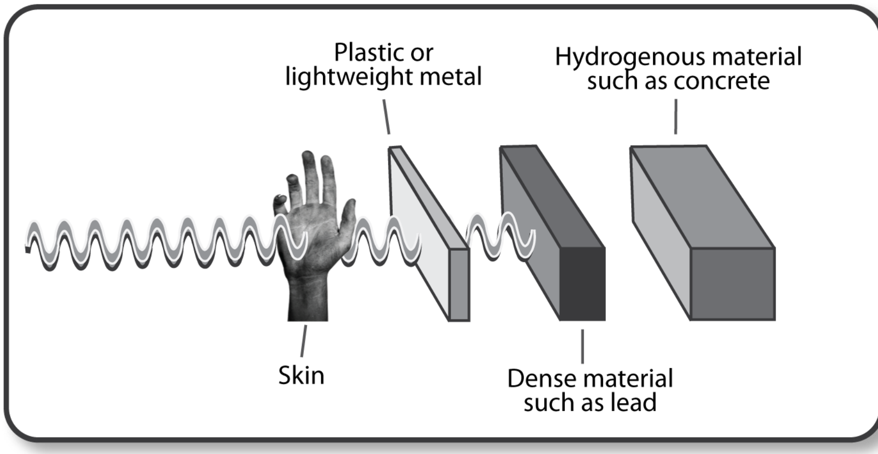
Gamma radiation (γ) is an electromagnetic wave or photon and has no electrical charge and no mass. Gamma rays are very similar to X-rays. The main difference between gamma rays and X-rays is that gamma rays originate inside the nucleus and X-rays originate outside the nucleus. Gamma rays are generally emitted from the nucleus during radioactive decay, while X-rays are emitted from orbital electrons. Electromagnetic radiation may also be given off by a charged particle accelerating in an electric field, which occurs in accelerators. Gamma radiation and X-ray radiation can ionize an atom by directly interacting with the electron(s).

Because gamma and X-ray radiation have no charge and no mass, they have a very high penetrating ability. They can travel very far through the air, up to several hundred feet. Gamma and X-ray radiation are best shielded by very dense materials, such as concrete, lead or steel.



Because gamma and X-ray radiation have the ability to penetrate through the body, they are considered a whole body, external hazard.

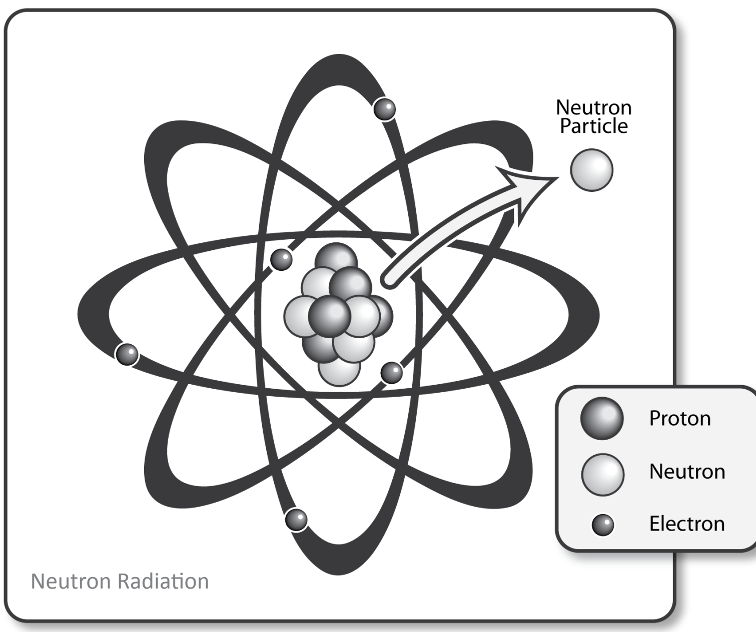
List the gamma and X-ray sources at your site:



Shielding of gamma and X-ray radiation. Gamma waves and X-rays can penetrate skin and typical plastic and light-weight metal. However, they do not pass readily through dense material such as lead.

Neutrons (n)

Neutron radiation (n) is a form of particle radiation that consists of neutrons ejected from the nucleus. Neutrons are emitted from the nucleus of an atom during the fission process (splitting of an atom), as well as the decay process of californium and other man-made radionuclides. Neutron radiation is also given off as secondary radiation from the interaction of other high-energy radiations with matter. A neutron has no electrical charge but has approximately the same mass as a proton. A direct interaction occurs as the result of a collision between a neutron and a nucleus. A charged particle or other ionizing radiation may be emitted during this direct interaction. So, at high energies, they transfer energy by collision with light atoms, especially hydrogen. At lower energies, neutrons can be absorbed and the absorbing material can become radioactive. The emitted radiation can cause ionization in human cells. This is called



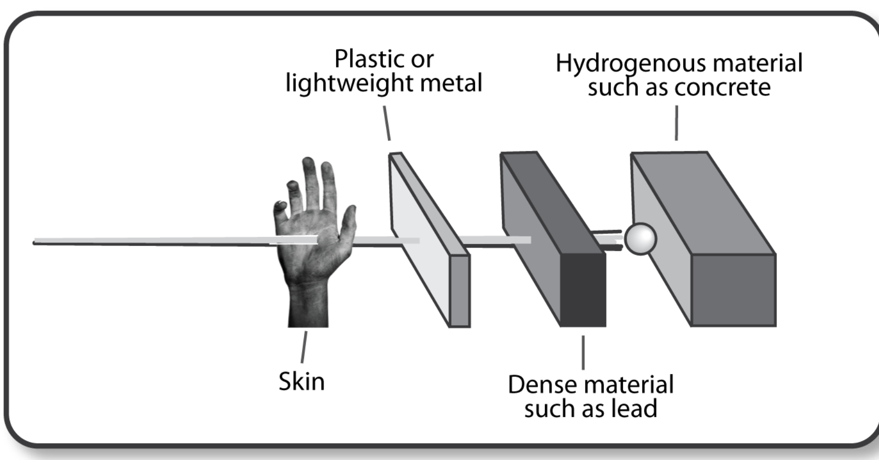
Neutron Radiation

"indirect ionization." Think of an out of control car smashing into other cars and the damage it will cause—this is similar to the damage neutrons can cause to living tissue.

Because they do not carry a charge, neutrons have a relatively high penetrating ability and are difficult to stop. They can travel very far in the air, easily several hundred feet. Neutron radiation is best shielded by materials with high hydrogen content, such as water, concrete, or plastic.

Since neutrons have the ability to penetrate the body, they are considered a whole body hazard.

List the neutron sources at your site:



Shielding of neutron radiation. Neutron radiation can penetrate skin, typical plastic and light-weight metal, and dense material such as lead. However, it does not pass readily through hydrogenous material such as concrete.

Summary of ionizing radiation types

Now that we have been introduced to the four types of ionizing radiation, take a moment to review the basic characteristics that make each one unique, as outlined in Table 2.2: Summary of Ionizing Radiation.

Table 2.2 Summary of Ionizing Radiation

Type of Radiation	Alpha (α)	Beta (β)	Gamma (γ) and X-ray	Neutron(n)
Physical Characteristic	Large mass with a +2 charge	Small mass with a -1 or +1 charge	- No mass or charge - Electromagnetic wave or photon - Similar to one another (difference is the place of origin)	- No charge - Has mass
Range	- Very short (about 1-2 inches in air) - Deposits large amount of energy in a short distance of travel	Short distance - 1 inch to 29 feet	- Range in air is very far - It will easily go several hundred feet - Very high penetrating power since it has no mass and no charge	- Range in air is very far - Easily can go several hundred feet - High penetrating power - Difficult to stop
Shielding	Few centimeters of air, sheet of paper, intact skin (outer layer)	Plastic, glass, safety glasses	Concrete, water, lead	Water, concrete, plastic (high hydrogen content)
Biological hazard	Internal hazard; it can deposit large amounts of energy in a small amount of body tissue	Internal hazard (this is due to short range). Externally, may be hazardous to skin and eyes.	Whole body exposure.The hazard may be external and/or internal. This depends on whether the source is inside or outside the body.	Whole body exposure. The hazard is generally external.

Objective 5: Identify the units used to measure radiation

There are several units for measuring radiation. Which one we use depends on what property of the radiation we want to measure. This is like the way we use different units in other measurements. For example, to measure the length of a dump truck, we use feet. To measure its capacity, we use cubic yards. To measure how fast it goes, we use miles per hour. These units all measure the same truck, but we use different units for different properties of the truck (length, capacity, speed, etc.).

There are several properties of radiation that we might measure: the energy of the radiation as it moves through the air, the amount of energy deposited in biological tissue, the effect of the radiation on tissue, the rate at which the energy is being deposited, the rate at which a radioactive material is disintegrating, etc.

Roentgen (R)

The roentgen is a unit for measuring external exposure (radiation from sources located outside of the body). It relates only to the effect on air and only applies to gamma and X-rays. Roentgens do not relate to biological effects of radiation on the human body. It is helpful to understand how to convert roentgens to milliroentgens (mR)

$$1R = 1000\ mR$$

Radiation absorbed dose (rad)

The rad is a unit for measuring absorbed dose in any material. Dose refers to the amount of energy deposited in body tissue due to radiation exposure. Rads apply to all types of radiation. This unit of measure does not take into account the potential effect that different types of radiation have on the body. You can convert rads to millirads as follows:

$$1\ rad = 1000\ mrad$$

Roentgen equivalent man (rem)

The rem is a unit for measuring dose equivalence. It is the most commonly used unit and pertains to the human body. The rem takes into account the energy absorbed (dose) and the biological effect on the body due to the different types of radiation. As a worker, this is a very important radiological unit to pay attention to.

The Radiation Weighting Factor (RWF)

RWFs
alpha = 20
beta = 1
gamma/x-ray = 1
neutron= 5-20

Some types of ionizing radiation do more damage to cells than other types. For example, alpha radiation ionizes a lot of atoms in a very short distance and, for the same amount of energy deposited as beta or gamma radiation, is 20 times more damaging to living cells. RWFs are used as a multiplier to reflect the relative amount of biological damage caused by the same amount of energy deposited in cells by the different types of ionizing radiation. The following is the equation that applies the RWF:

$$rem = rad \times RWF$$

For example, 0.5 rad of an alpha radiation source would equal 10 rems:

$$0.5\,rad \times 20 = 10\,rem$$

Whereas 0.5 rad of a beta radiation source would equal 0.5 rems:

$$0.5\,rad \times 1 = 1\,rem$$

We will be able to see how these values affect us as radiological workers in Module 4, where we discuss radiation dose limits.

Note: Prior to 2007, when the DOE updated its dosimetric models and terminology, the DOE used a Quality Factor (QF). The quality factor was applied to the absorbed dose at a point in order to take into account the differences in the effects of different types of radiation. Now, for radiological protection purposes, the absorbed dose is averaged over an organ or tissue and this absorbed average dose is weighted for the radiation quality in terms of the radiation weighting factor.

Radiation dose and dose rate

While dose is the amount of radiation you receive (amount of energy deposited), radiation dose rate is the dose per unit of time.

Examples are:

- Radiation dose rate = dose/unit of time
- Radiation equivalent dose rate = mrem/hr
- Radiation absorbed dose rate = mrad/hr

Table 2.3 Summary of Radiation Units		
R	rad	rem
Unit for measuring exposure.	Unit for measuring absorbed dose in any material.	Unit for measuring dose equivalence (most commonly used unit).
Defined only for effect on air.	Defined for any material.	Pertains to human body.
Applies only to gamma and X-ray radiation.	Applies to all types of radiation.	Applies to all types of radiation.
Does not relate biological effects of radiation to the human body	Does not take into account the potential effect that different types of radiation have on the human body.	Takes into account the energy absorbed (dose) and the biological effect on the body due to the different types of radiation. Equal doses of different types of radiation (as measured in rad) can cause different levels of damage to the human body (measured in rem).

Objective 6: Convert rem to millirem and millirem to rem

Convert 5 rem to millirem

Convert 1200 millirem to rem

List any site-specific information about radiological fundamentals below or, any concerns you have after reviewing this module.

Review Questions

1. The three basic parts of an atom are the:

a. ________________________________

b. ________________________________

c. ________________________________

2. State the charge of the particles and their location within the atom:

PARTICLE LOCATION CHARGE

a. Electron _____________ _________

b. Neutron _____________ _________

c. Proton _____________ _________

3. Ionization is the process of ____________________ electrons from

______________. Electrons will be removed if enough ________________is sup

plied.

4. The four basic types of ionizing radiation are

a. _______________

b. _______________

c. _______________ or _______________

d. _______________

5. Radioactive _______________ is radioactive material in an unwanted place.

6. _______________ radiation doesn't have enough energy to _______________ an atom.

7. _______________ is the process of radioactive atoms becoming stable by emitting
_______________.

8. Radioactive ___________-___________ is the time it takes for one half of the radioactive atoms to decay.

9. The units used to measure radiation are:

a. ____________________

b. ____________________

c. ____________________

10. The units used to measure contamination or radioactivity are

a. _____________________________

b. _____________________________

c. _____________________________

11. Complete the following conversions.

a. 1000 mrem = _____________ rem

b. 350 mrem = _____________ rem

c. 2500 mrad = _____________ rad

d. 0.50 rem = _____________ mrem

e. 1.25 rem = _____________ mrem

12. Fill in the following summary of ionizing radiation table:

Summary of Ionizing Radiation				
Type of Radiation	Alpha (α)	Beta (β)	Gamma (γ) and X-ray	Neutron(n)
Physical Characteristic				
Range				
Shielding				
Biological Hazard				

Notes:

Module 3: Biological Effects of Radiation

Objectives

Equipment operators demolishing an above-ground tank at the Hanford DOE site.

At the end of this module, you will be able to:

- Identify the major sources of natural, background and manmade radiation and the average annual dose of each received by the general population
- State the method by which radiation causes damage to cells
- Identify the possible effects of radiation on cells
- Define the terms "acute dose" and "chronic dose" and state examples of chronic radiation dose
- Define the terms "somatic effect" and "heritable effect"
- State the potential effects associated with prenatal radiation dose
- Compare the biological risks to the general population from chronic radiation doses and the risks to health workers who are subjected to radiation in their daily work

Purpose of the module

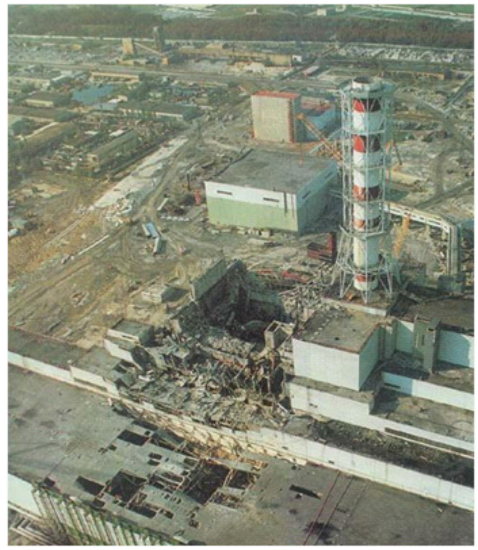
The purpose of this module is to build an understanding of how and why radiation harms the human body. In the last module, we learned about atoms and how atoms can become radioactive and the definition of ionizing radiation. The next step in our learning path is to see how radiation affects our bodies so that we can protect ourselves as we work with radiological materials.

In this module, we will discuss the potential for biological effects and risks due to ionizing radiation and put these potential risks into perspective when compared to other occupations and daily activities. With this information, it is hoped that workers will develop a healthy respect for radiation rather than fear or disregard. Think of firefighters who enter a burning structure, they do not fear the fire, but respect it. They gained a respect for the power of fire through training. It is the same with radiation—your radiological worker training should help you develop a respect for radiation, along with a strong understanding of how to protect yourself from it.

How did we learn about the biological effects of radiation?

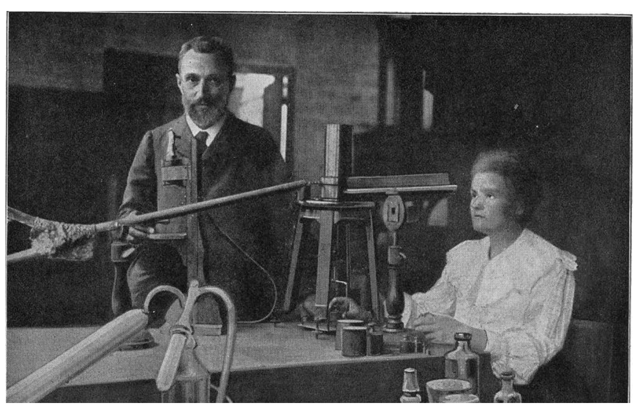
The fact that ionizing radiation produces biological damage has been known for many years. We have gained most of our knowledge of these effects since World War II.

We know more about the biological effects of ionizing radiation than most other environmental factors. Rather than just being able to base our information on animal studies, we have a large body of information available regarding exposures to humans. There are four major groups of people that have been exposed to significant levels of radiation.



This photo shows the aftermaths of the Chernobyl nuclear plant incident which took place on April 26, 1986 in the Ukrainian Republic of the former Soviet Union.

1. The first group includes early radiation workers, such as radiologists. These workers received large doses of radiation before the biological effects were recognized. Since that time, standards have been developed to protect workers. For example, Marie Curie, the Polish physist and chemist was a pioneer in the field of radioactivity. She died in 1934 from aplastic anemia most likely caused by exposure to radiation throughout her career.



Pierre and Marie Curie in the laboratory. Prior 1907.

2. The second group is the more than 250,000 survivors of the atomic bombs dropped at Hiroshima and Nagasaki. Some of these survivors received doses estimated to be in excess of 50,000 mrem.

Ground zero of Nagasaki, Japan. Courtesy Yosuke Yamahata.

3. The third group includes individuals who have been involved in radiation accidents, such as the Chernobyl incident which took place in 1986. According to a 2005 report issued by the Chernobyl Forum, 28 emergency workers died from Acute Radiation Syndrom (ARS), and roughly estimates that cancer deaths caused by the Chernobyl accident may be as high as 4,000 among the total 600,000 cleanup workers who received the highest exposure levels. These totals do not include an additional 5,000 deaths due to exposure among the surrounding population.

4. The fourth and largest group of individuals are patients who have undergone radiation therapy for cancer and other diseases.

Objective 1: Identify the major sources of natural, background and manmade radiation and the average annual dose of each received by the general population

Sources of radiation

The earth has always been a radioactive planet. Human beings have always lived in the presence of natural, background radiation. The majority of the earth's population will be exposed to more ionizing radiation from natural, background radiation than from occupational exposures.

The average annual radiation dose equivalent for a member of the general population from both natural and manmade, background sources is about 360 mrem.

Sources of background radiation include cosmic, terrestrial, dietary intake, medical, consumer products, and other means.

Natural radiation sources

Several sources of radiation occur naturally. The radiation emitted from these sources is identical to the radiation remitted from manmade sources. The four major sources of naturally occurring radiation are:

- Cosmic radiation
- Sources found in the Earth's crust, known as terrestrial radiation
- Sources found in the human body, known as internal sources
- Radon

Cosmic radiation

Cosmic radiation comes from outer space and our own sun. The earth's atmosphere and magnetic field affect the levels of cosmic radiation that reach the surface. As a result, the amount of cosmic radiation you receive is determined by where you live. For example, the dose rate on Long Island (at sea level) is about 24 mrem/ year, while the dose rate in Denver, Colorado is 50 mrem/year. The higher up you are the less the Earth's protective atmosphere can "filter" out the cosmic radiation. The average dose from cosmic radiation in the U.S. is 28 mrem/year.

Space contains cosmic radiation.

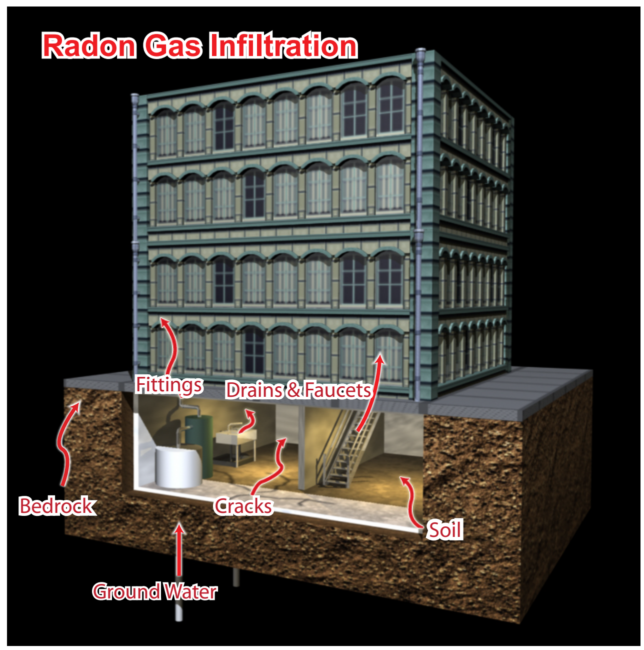
Terrestrial radiation

Terrestrial sources exist because a number of materials have remained radioactive since the formation of the earth. These natural radioactive materials are found in the ground, rocks and building materials. Some of the contributors to terrestrial sources are the naturally radioactive elements radium, uranium, and thorium. In fact, there are some areas in Brazil and India where the natural, background radiation levels reach 3,000 mrem/year. The average dose from terrestrial sources in the United States is 28 mrem/year.

Internal sources

Our bodies contain various, naturally occurring radioactive elements. The food we eat and the water we drink contain trace amounts of natural radioactive materials. These naturally occurring radioactive materials deposit in our bodies and cause internal exposure to radiation. Some naturally occurring radioactive isotopes include sodium-24 (Na-24), carbon-14 (C 14), argon-41 (Ar-41), and potassium-40 (K-40). Most of our internal exposure comes from K-40. The average dose from internal sources in the United States is about 40 mrem/year.

Radon



Radon gas infiltrates structures through bedrock, ground water, soil, structural cracks, drains, faucets, and fittings.

Radon-222 comes from the radioactive decay of uranium, which is naturally present in the soil. The radon gas can migrate through the soil into the air. The decay products of radon may be inhaled, which will then deliver a dose to the tissue of the lungs. Radon can also be ingested through drinking water. Radon is often the single largest contributor to an individual's background radiation dose and is variable from location to location. According to the EPA, radon gas is the second largest cause of lung cancer in America, after smoking. The average effective dose equivalent from radon in the United States is 200 mrem/year. Radon emits alpha radiation. It presents a hazard only when taken into the body.

Manmade sources of radiation

The difference between manmade sources of radiation and naturally occurring sources is the origin of the radiation, i.e., where the radiation is either produced or enhanced by human activities.

The four top sources of manmade radiation exposures are:

- Tobacco products (cigarettes, cigars etc. Although the tobacco is not man-made, the products are)
- Medical uses
- Building materials
- Domestic water supply (radon)

In addition to other harmful chemicals, tobacco products contain radioactive materials!

Tobacco products

Cigarettes contain polonium-210 and lead-210, which are both radioactive atoms. It is estimated that the average contributed dose to smokers through tobacco products is 1300 mrem/yr.

Medical uses

A medical X-ray station.

Use of radiation in health care procedures accounts for a total average dose of ~300 mrem/yr for each individual. This can be further broken down into the following categories:

- Computed tomography: total average dose ~150 mrem/yr
- Nuclear medicine: total average dose ~75 mrem/yr
- Radiography/fluoroscopy: total average dose ~75 mrem/yr

In addition to X-rays, radioactive materials and radioactive sources are used in medicine for diagnosis and therapy.

Building materials


Concrete blocks.
Courtesy OSHA.

Different building materials contribute roughly ~7 mrem total average dose each year. This includes mainly stone, brick and concrete. Although wood can also contain radioactive atoms.

Domestic water supply


Water from a faucet.

With the invention of wells and elaborate piping systems to access ground water, radon in potable water has become a concern. Radon can become trapped in water. When the water enters your home it can be released from the running water into the air and potentially be inhaled by you. It can also enter your body when you drink water from your tap. The average total annual dose of radon in water is ~5 mrem/yr.

Other minor contributors of radiation


A smoke detector containsa small amount of radioactive material.

Other contributors to radiation dose include consumer products, industrial sources, and atmospheric testing of nuclear weapons.

Some consumer products contain small amounts of radioactive material. Examples include certain ceramic dishes (usually with an orange glaze), some luminous dial watches, and some smoke detectors. These consumer products account for a very minor contribution to the background dose. The average dose from consumer products in the United States is ~10 mrem/yr.

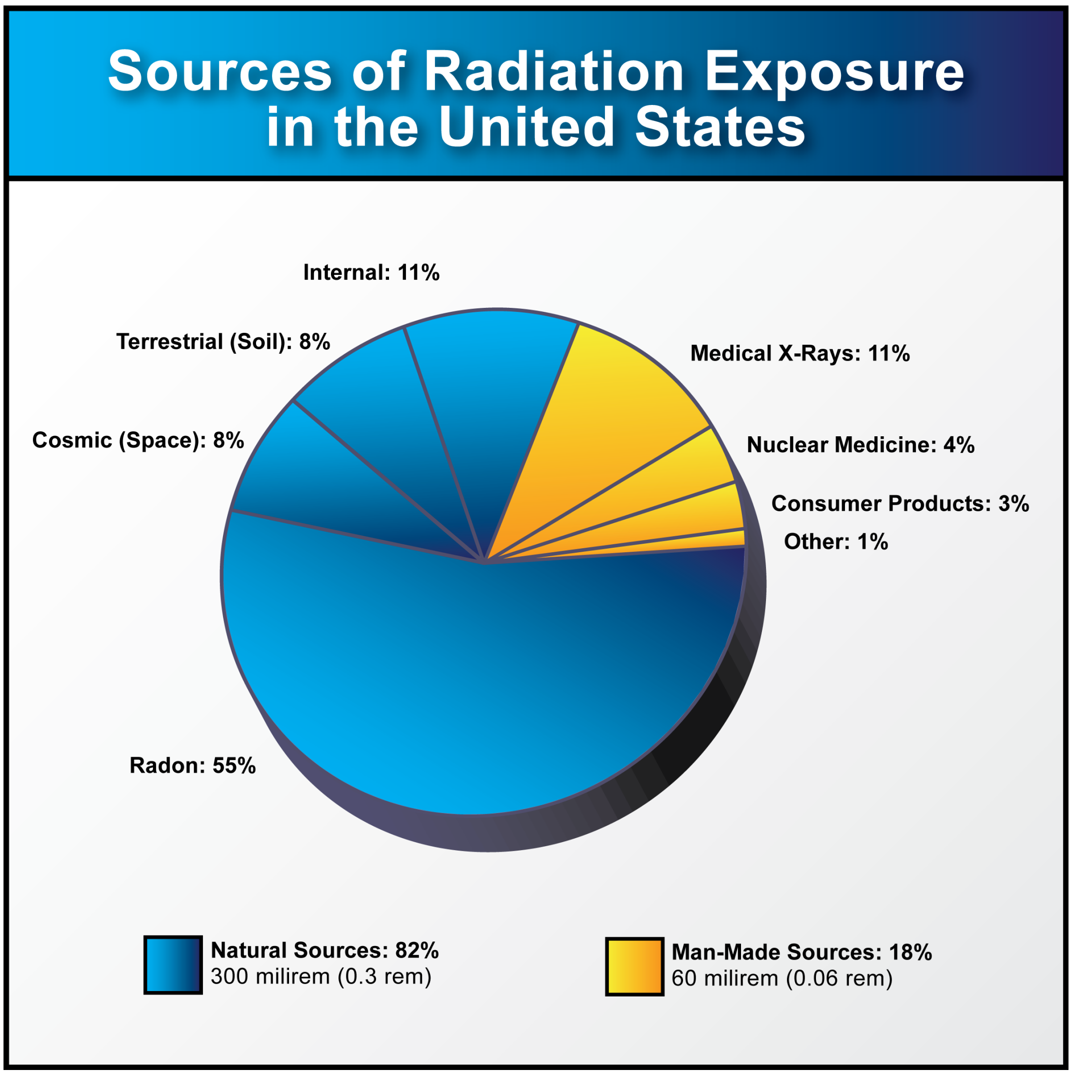
Another manmade source of radiation is residual fallout from atmospheric nuclear weapons testing in the 1950s and early 1960s or from accidents, such as

Chernobyl. Nuclear weapons testing is now banned by most nations. The average annual dose from residual fallout is less than 2 mrem/yr.

Industrial uses of radiation include X-ray machines used for baggage inspection, manufacturing the equipment, video display terminals, and tungsten welding rods.

Average annual dose from all radiological sources

The average annual, total effective dose to the general population (non-smokers) from naturally occurring and manmade sources is 360 mrem.



Objective 2: State the method by which radiation causes damage to cells

How did we learn about the effects ionizing radiation has on humans?

Information about the biological effects of radiation is available not only from animal studies but also from studies of human exposures. Four major groups of people that have been exposed to significant levels of radiation are:

- Early workers, such as radiologists who received large doses of radiation before the biological effects were recognized and before standards were developed to protect workers
- More than 250,000 survivors of the atomic bombs dropped at Hiroshima and Nagasaki who received estimated dose equivalents in excess of 50,000 mrem (50 rem)
- Individuals who have been involved in radiation accidents, the most notable being the Chernobyl accident
- Patients who have undergone therapeutic radiation treatments

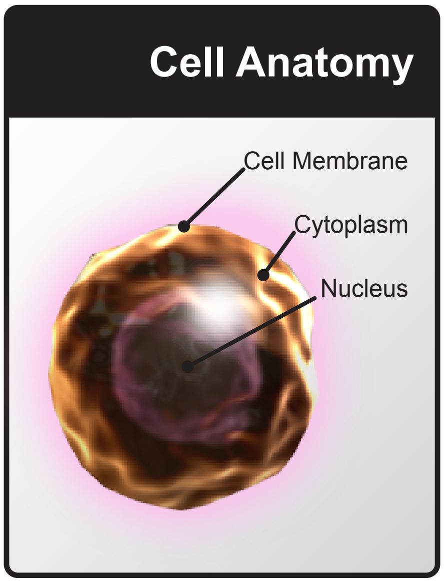
Effects of ionizing radiation on cells

The human body is made up of many organ systems. We arrive there by taking a collection of atoms to make molecules, the molecules combine to make specialized cells, a group of specialized cells makes tissue, tissue makes up organs and a group of organs can make up a system—and there we have the human body!

Biological effects of radiation begin with the ionization of atoms! The method by which radiation causes damage to human cells is by ionization of atoms in the cells. It may also cause excitation. Excitation is where the radiation deposits energy into an atom raising its energy level but not raising the level enough to eject a bound electron. Atoms are the building blocks of the cells that make up the tissues of the body. Any potential radiation damage begins with damage to atoms.

A cell is made up of two principal parts, the body of the cell and the nucleus. The nucleus is like the brain of the cell. When ionizing radiation hits a cell, it may strike a vital part of the cell like the nucleus or a less vital part of the cell, like the cytoplasm.

Let's take a closer look at cells, what they are, and what they do



Cells are tiny living organisms that make up the human body. The human body contains about 50,000 billion cells. Each cell consists of:

- A cell membrane
- Cytoplasm
- A nucleus

The cell consists of an outer membrane that contains an inner watery substance called cytoplasm. Cytoplasm contains a variety of substances, such as proteins, sugars, and amino acids. At the center of the cell is the nucleus, home of the genetic blueprint "Deoxyribonucleic Acid" (DNA). This DNA molecule contains all the information that governs what the cell is and what it does. The nucleus is the brain of the cell.

Cells contain a set of large molecules called DNA (deoxyribonucleic acid). DNA tells the cell how to be the way it's supposed to be and to do what it's supposed to do. The DNA is like an encyclopedia. Each cell has the complete set of information for every cell. But a cell only uses that part of the information that pertains to it. Each "volume" in the "encyclopedia" is called a chromosome. Each "article" on a particular subject is a gene. A gene is a part of a DNA molecule that has information for a particular trait, such as what size the cell should be, or with what chemicals it should react. Because the information is in the genes, it's called genetic information. The chromosomes, each containing many, many genes, all made of DNA, are found in the nucleus.

Cell sensitivity to ionizing radiation

Some cells are more sensitive than others to environmental factors, such as viruses, toxins, and ionizing radiation. Cells can be divided into two general types: actively dividing and less actively dividing. Actively dividing cells are more sensitive to the effects of ionizing radiation. Actively dividing cells include:

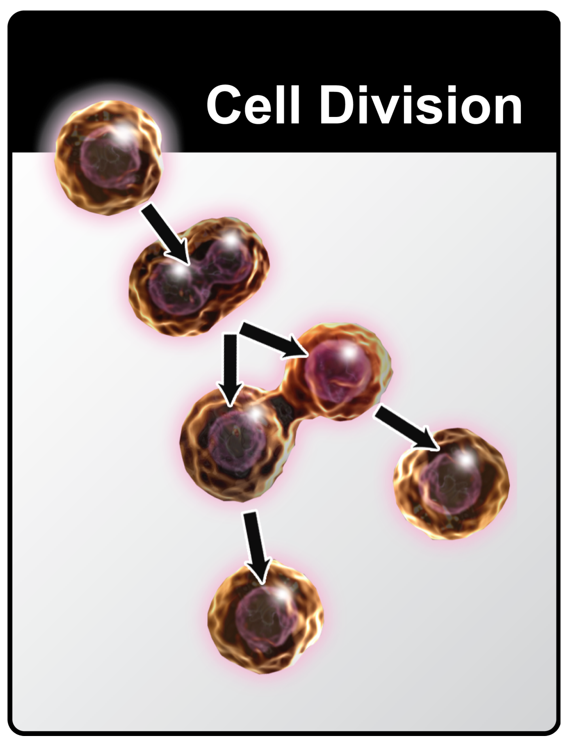
- blood-forming cells
- the cells that line our intestinal tract
- hair follicles
- cells that form sperm

Less actively dividing and more specialized cells that are less sensitive to the effects of ionizing radiation include:

- Brain cells
- Muscle

Cell division

An individual cell can divide to make two new cells. The new cells are called "daughter" cells. Cells divide for two reasons. Cell division is the mechanism by which we grow. A human being develops from a single cell (which forms from the union of a sperm and an egg). That single cell divides to form two cells, each of which divide again, and again until there are the trillions of cells that make up a person. During this process the dividing cells also "differentiate" (specialize). Some become skin cells, some are brain cells, some are liver cells, etc. The other reason that cells divide is to produce new cells that replace worn out ones. For example, cells in the lower layer of



The process of cell division.

skin divide to make replacements for cells in the outer layer that have worn out and died. This process happens continuously since skin cells only live for a few days. A similar process happens inside the intestines, whose cells, like the skin, are constantly and quickly replaced. Cells in the scalp also divide quickly, in order for hair to grow. Other cells divide less rapidly. For example, cells in the brain and nervous system. A nerve cell lasts many years without dividing.

Cell division is illustrated in the graphic to the right. First the chromosomes in the cell's nucleus make a copy of themselves. Then the nucleus divides. Each of the two new nuclei has a complete set of chromosomes. Then the cell itself divides. Each new cell has one of the nuclei.

Objective 3: Identify the possible effects of radiation on cells

Four possible effects of radiation on cells

Several things can happen when a cell is exposed to ionizing radiation. The following are possible effects of radiation on a cell:

- There is no damage
- Cells are damaged but are able to repair the damage and operate normally
- Cells are damaged and operate abnormally
- Cells die as a result of the damage

There is no damage

If ionizing radiation passes into the cell and does not damage anything, that is a good thing for workers! However, we cannot rely on this to always happen. Also, ionizing radiation is a carcinogen, and according to the National Institute for Occupational Safety and Health there is no safe exposure level for a carcinogen. This means workers should attempt to have zero exposure to carcinogens.

Cells are damaged but are able to repair the damage and operate normally

The body of most cells is made up primarily of water. When ionizing radiation hits a cell, it is most likely to interact with the water in the cell. One of the by-products of radiation-induced ionization of water is hydrogen peroxide. Hydrogen peroxide can damage a cell's atomic structures.

Ionizing radiation can also hit the nucleus of the cell. The nucleus contains the vital parts of the cell, such as chromosomes. The chromosomes determine cell function. When chromosomes duplicate themselves, the chromosomes transfer their information to new cells. Radiation may cause a change in the chromosome that does not affect the cell.

Damage to chromosomes and other cell structures can be repaired. In fact, our bodies repair a very large number of chromosome breaks every day.

Cells are damaged and operate abnormally

Cell damage may not be repaired or may be only partially repaired. In that case, the cell may not be able to function properly. It is possible that a chromosome in the cell nucleus could be damaged but not be repaired correctly. If the cell continues to reproduce, this is called a mutation and may result in cancer.

Cells die as a result of the damage

At any given moment, thousands of our cells die and are replaced by normal functioning cells. However, the radiation damage to a cell may be so extensive that the cell dies prematurely.

Objective 4: Define the terms "acute dose" and "chronic dose" and state examples of chronic radiation dose

Acute and Chronic radiation dose

Potential biological effects depend on how much and how fast a radiation dose is received. Radiation doses can be grouped into two categories: acute and chronic.

Acute dose

High doses of radiation received in a short period of time are called acute doses. The body's cell repair mechanisms are not as effective on damage caused by an acute dose. As we shall soon learn, acute radiation exposure can have different effects depending on whether it occurred to the whole body or to specific parts of the body.

Acute radiation effects typically will not occur at doses less than 10 rad. Below this level, the effect of radiation is too small to detect with today's routine medical technology. The first detectable effect is a minor change in the concentration of white and red blood cells. As the cumulative dose increases in magnitude, the effects become more observable. Examples of expected effects versus radiation dose include:

- 25 rad - Onset of minor observable blood changes
- 100 rad - May observe radiation sickness symptoms (nausea, diarrhea)
- 300 rad - Possible reddening of the skin, loss of hair
- 450 rad - Established lethal dose LD50/60 (With no medical attention, expect 50% mortality within 60 days)

Results of 6.5 hour exposure to a 26 Ci iridium-192 source placed in a back pocket. Photo progression is 3 and 10 days after exposure. Courtesy CDC.

Acute doses to the whole body

After an acute dose, damaged cells may be replaced by new cells and the body may repair itself, although this may take a number of months. Only in extreme cases, such as with the Chernobyl firefighters (500 rem), would the dose be so high as to make recovery unlikely.

Acute doses to only part of the body

X-ray machines

It is possible that radiation exposure may be limited to a part of the body, such as the hands.

There have been accidents, particularly with X-ray machines, in which individuals have exposed their fingers to the intense radiation beam. In some of these cases, individuals have received doses of millions of mrem to their fingers. Some of these individuals have lost one or more of their fingers. It is important for individuals who work with X-ray or similar equipment to be trained in the safe use of this equipment.

Radiation therapy

Radiation therapy patients receive high doses of radiation in a short period of time, but generally only to a small portion of the body (not a whole body dose). The skin and limited tissue of these patients may receive significant doses, but doses to the region of a tumor are many times higher. Ionizing radiation is used to treat cancer in these patients because cancer cells are rapidly dividing and therefore sensitive to ionizing radiation. Some of the side effects of people undergoing radiation therapy are hair loss, nausea, and tiredness.

Probability of a large acute dose

What is important to understand is that it takes a large acute dose of radiation before any physical effect is seen. These acute doses have occurred in Hiroshima/Nagasaki, and in a few radiation accidents, including Chernobyl. The possibility of a radiological worker receiving a large acute dose of ionizing radiation on the job is extremely low. Typically, radioactive materials are handled in small quantities that do not produce large amounts of radiation. Where there is a potential for larger exposures, many safety features are required.

Chronic dose

In this course, a chronic dose is one received over a long period of time, usually repeatedly, in small increments. Examples of chronic doses include the dose received by an Operating Engineer while conducting radiological work (occupational dose) and the dose from background sources. Chronic doses may present an increased risk of a radiation-induced cancer developing later in life. There are no observable short-term effects associated with a chronic radiation dose. Within the allowed dose limits, this increased risk of a radiation-induced cancer is considered small, especially when compared to risks people accept in their everyday lives.

Objective 5: Define the terms "somatic effect" and "heritable effect"

Biological effects of radiation exposure

Somatic effects refer to the effects radiation has on the individual receiving the dose. Genetic effects refer to mutations due to radiation damage to the DNA of a cell. When this change is in the DNA of parental reproductive cells, it is called a heritable effect.

Somatic effects

Somatic effects can best be described in terms of prompt and delayed effects, as discussed below.

Prompt effects

Although rare in the nuclear industry, large doses are typically acute radiation doses representing serious overexposures. The biological effects of large acute doses are as follows in Table 3.1:

Table 3.1 Outcomes of acute radiation doses

Sources of Radiation	Approximate Dose (rem)
Chest x-ray	up to 0.03
Average annual dose from cosmic radiation to people living in Rocky Mountain states	0.06 - 0.08
Average annual dose from exposure to natural sources of ionizing radiation to the US population (e.g., radon, cosmic rays)	0.2 - 0.3
CAT scan (whole body)	1
Recommended annual occupational exposure limit, excluding personal medical exposures and exposures from natural sources	up to 5 rem per year
No symptoms	15
No symptoms of illness; minor and temporary drop in counts of white blood cells and platelets	50
Possible Accute Radiation Syndrome: 10% of exposed individuals may have nausea/vomiting within 48 hours and a mild drop in blood counts	100
50% of exposed individuals will die within 30 days in the absense of appropriate medical care (LD 50/30)	300-400

Delayed effects

Delayed effects may result from either a single large acute overexposure or from continuing low-level chronic exposure. Cancer in its various forms is the most important potential delayed effect of radiation exposure. Other effects noted include cataracts, life shortening, and for individuals exposed in the womb, lower IQ test scores.

Heritable effects

A heritable effect is a physical mutation or trait that is passed on to an offspring. In the case of heritable effects, the parental individual has experienced damage to some genetic material in the reproductive cells and has passed the damaged genetic material on to the offspring.

Heritable effects from radiation have never been observed in humans but are considered possible. They have been observed in studies of plants and animals. Heritable effects have not been found in the 77,000 Japanese children born to the survivors of Hiroshima and Nagasaki (these are children who were conceived after the atom bomb, i.e., heritable effects). Studies have followed these children, their children, and their grandchildren.

Factors affecting biological damage due to exposure to radiation

Total dose

In general, the greater the dose, the greater the potential for biological effects.

Dose rate (how fast)

The faster the dose is delivered, the less time the body has to repair itself.

Type of radiation

For example, internally deposited Alpha emitters are more damaging than Beta or Gamma emitters for the same energy deposited. Alpha emitters deposit energy in a very small mass, Beta and Gamma emitters deposit their energy over a larger mass.

Area of the body that receives a dose

In general, the larger the area of the body that receives a dose, the greater the biological effect. Extremities are less sensitive than blood forming and other critical organs. That is why the annual dose limit for extremities is higher than for a whole body dose that irradiates internal organs.

Cell sensitivity

The most sensitive cells are those that are rapidly dividing. Examples include blood cells, hair follicles, and the cells lining the gastrointestinal tract.

Individual sensitivity

Some individuals are more sensitive to environmental factors such as ionizing radiation.

The developing embryo/fetus is the most sensitive to environmental factors. Children are more sensitive than adults. This is due to their having large numbers of rapidly dividing cells.

In general, the human body becomes relatively less sensitive to ionizing radiation with increasing age. The exception is that elderly people are more sensitive than middle-aged adults, due to their inability to repair cell damage as quickly (less efficient cell repair mechanisms).

Objective 6: State the potential effects associated with pre-natal radiation dose

Prenatal radiation exposure

Although no effects were seen in Japanese children conceived after the atomic bomb, there were effects seen in some children who were in the womb when exposed to the atomic bomb radiation at Hiroshima and Nagasaki. Some of these children were born with a slightly smaller head size, lower average birth weight, and increased incidence of mental retardation. Some children showed lower IQ test scores and slower scholastic development later in life. Smaller physical size and increased incidence of behavioral problems were also observed.

A fetus has a risk of developing adverse health affects if exposed to ionizing radiation.

Sensitivity of the fetus

Embryo/fetal cells are rapidly dividing, which makes them sensitive to many environmental factors, including ionizing radiation. The embryo/fetus is most susceptible to developing adverse health effects if exposed during the time period of 8 - 15 weeks after conception.

Factors for potential effects associated with prenatal exposures

Many chemical and physical (environmental) factors are suspected of causing or known to have caused damage to fetuses, especially early in the pregnancy. Radiation, alcohol consumption, exposure to lead, and heat, such as from hot tubs, are only a few such factors.

Risks in perspective

Current radiation protection standards and practices are based on the premise that any radiation dose, no matter how small, can result in health effects such as cancer. Further, it is assumed that these effects are produced in direct proportion to the dose received (e.g., doubling the radiation dose results in a doubling of the risk of the effect). These two assumptions lead to a dose-response relationship, often referred to as the linear, no-threshold model, for limiting health effects at very low radiation dose levels.

However, it should be noted that this is a conservative assumption made in the absence of more conclusive evidence. Health effects (primarily cancer) have been observed in humans only at doses in excess of 10 rem delivered at high dose rates. Below this dose, estimation of adverse health effects is speculative. Risk estimates that are used to predict health effects in exposed individuals or populations are based on epidemiological studies of well-defined populations (e.g., the Japanese survivors of the atomic bombings in 1945 and medical patients who underwent radiation treatment) exposed to relatively high doses delivered at high dose rates. It is generally accepted that studies have not demonstrated adverse health effects in individuals exposed to small doses (less than 10 rem) delivered over a period of many years.

Objective 7: Compare the biological risks from chronic radiation doses to health risks workers are subjected to in industry and daily life

Risk from exposures to ionizing radiation

No increases in cancer have been observed in individuals who receive a dose of ionizing radiation at occupational levels. The possibility of cancer induction cannot be dismissed even though an increase in cancers has not been observed. Risk estimates have been derived from studies of individuals who have been exposed to high levels of radiation.

The risk of cancer induction from radiation exposure can be put into perspective. This can be done by comparing it to the normal rate of cancer death in today's society. The current rate of cancer death among Americans is about 20 percent. Taken from a personal perspective, each of us has about 20 chances in 100 of dying of cancer. A radiological worker who receives 25,000 mrem over a working life increases his/her risk of cancer by 1 percent, or has about 21 chances in 100 of dying of cancer. A 25,000 mrem dose is a fairly large dose over the course of a working lifetime. The average annual dose to DOE workers is less than 100 mrem, which leads to a working lifetime dose (40 years assumed) of no more than approximately 4,000 mrem.

Comparison of risks

Table 3-2 compares the estimated days of life expectancy lost as a result of exposure to radiation and other health risks. The following information is intended to put the potential risk of radiation into perspective when compared to other occupations and daily activities.

Table 3.2 Estimated Loss of Life Expectancy from Health Risks

Health Risk	Estimated Loss of Life Expectancy
Smoking 20 cigarettes a day	6 years
Overweight (by 15%)	2 years
Alcohol consumption (U.S. average)	1 year
Agricultural accidents	320 days
Construction accidents	227 days
Auto accidents	207 days
Home accidents	74 days
Occupational radiation dose (1 rem/y), from age 18-65 (47 rem total) *	51 days
All natural hazards (earthquakes, lightning, flood)	7 days
Medical radiation	6 days
* Note: the average DOE radiation worker receives less than 0.1 rem/yr	

Reference: NCRP Report #93, "Ionizing Radiation Exposure of the Population of the United States" (1987).

The estimates in Table 3-2 indicate that the health risks from occupational radiation doses are smaller than the risks associated with normal day-to-day activities that we have grown to accept.

Acceptance of a risk is a personal matter and requires a good deal of information and training to allow you, as a worker, to make informed judgments. However, with this in mind, your employer should be using all feasible methods to reduce your risk to the occupational hazard of radiation exposure and contamination. We will look at some of these methods in the following modules. It is the responsibility for your employer to make sure the health and safety programs and work methods required by the DOE (or OSHA if not a DOE site) are implemented and followed. With this said, you as a radiological worker, must understand those programs and procedures and be able to follow and use them, as well as, be able to identify and report when they are not in place. This may require you to seek help from your co-workers and your Unions!

The risks associated with occupational radiation doses are generally considered acceptable by most scientific groups who have studied them as compared to other occupational risks. There are some scientific groups who claim that the risk is too high. The DOE continues to fund and review worker health studies to address these concerns.

Activity 3.1: Calculate your radiation dose with the EPA radiation dose calculation tool

Time for activity: 10 minutes (five minutes to fill in the calculation sheet and five minutes for group discussion).

Objectives: To give participants practice in calculating their annual radiation dose by use of the EPA radiation dose tool or through the radiation dose table.

Task method 1: Individually or in pairs, go to a computer station and log on to the site listed below:

http://www.epa.gov/radiation/understand/calculate.html

Once on the EPA site, calculate your total annual radiation dose. If you don't have access to a computer station, use the table to calculate your dose (see Task method 2 below). Once you have found your annual dose, discuss your findings with the class.

Task method 2: Individually fill out the annual radiation dose chart below from the American Nuclear Society. Once you have found your annual dose, discuss your findings with the class.

Estimate Your Personal Annual Radiation Dose

FACTORS	COMMON SOURCES OF RADIATION		YOUR ANNUAL DOSE (MREMS)
WHERE YOU LIVE	**Cosmic radiation** (from outer space) Exposure depends on your elevation (how much air is above you to block radiation). Amounts are listed in mrem (per year). At sea level..........26 mrem 2-3000 ft.............35 mrem 6-7000 ft.............66 mrem 0 - 1000 ft...........28 3-4000 ft.............41 7-8000 ft.............79 1-2000 ft.............31 4-5000 ft.............47 8-9000 ft.............96 5-6000 ft.............52 [Elevation of cities (in feet): Atlanta 1050; Chicago 595; Dallas 435; Denver 5280; Las Vegas 2000; Minneapolis 815; Pittsburgh 1200; St. Louis 455; Salt Lake City 4400; Spokane 1890.]		______ mrem
	Terrestrial (from the ground) If you live in a state that borders the Gulf or Atlantic Coasts, add 16 mrem If you live in the Colorado Plateau area (around Denver), add 63 mrem If you live anywhere else in the continental US, add 30 mrem.		______ mrem
	House Construction If you live in a stone, adobe, brick or concrete building, add 7 mrem		______ mrem
	Power Plants If you live within 50 miles of a nuclear power plant, add 0.01 mrem If you live within 50 miles of a coal-fired power plant, add 0.03 mrem		______ mrem
FOOD WATER AIR	**Internal Radiation***** From food (Carbon-14 and Potassium-40) & from water (radon dissolved in water)		40 mrem
	From air (radon)		200 mrem
HOW YOU LIVE	Weapons test fallout (less than 1)*	1 mrem	1 mrem
	Jet Plane Travel	0.5 mrem per hour in the air	______ mrem
	If you have porcelain crowns or false teeth**	0.07 mrem	______ mrem
	If you wear a luminous wristwatch	0.06 mrem	______ mrem
	If you go through luggage inspection at airport	0.002 mrem	______ mrem
	If you watch TV*	1 mrem	______ mrem
	If you use video display terminal (computer screen)*	1 mrem	______ mrem
	If you have a smoke detector	0.008 mrem	______ mrem
	If you use a gas camping lantern	0.2 mrem	______ mrem
	If you wear a plutonium-powered pacemaker	100 mrem	______ mrem
MEDICAL TESTS	**Medical Diagnostic Tests –** Number of ***millirems per procedure*** X-Rays: Extremity (arm, hand, foot, or leg).........1 Dental.........1 Chest........6 Pelvis/hip ......65 Skull/neck..... 20 Barium enema.....405 Upper GI......245 CAT Scan (head and body)..........110 Nuclear Medicine (e.g., thyroid scan)........14		______ mrem
	YOUR ESTIMATED ANNUAL RADIATION DOSE		______ mrem

* The value is less than 1, but adding a value of 1 would be reasonable.

** Some of the radiation sources listed in this chart result in an exposure to only part of the body. For example, false teeth or crowns result in a radiation dose to the mouth. The annual dose numbers given here represent the "effective dose" to the whole body.

*** Average values.

Primary sources for this information are National Council on Radiation Protection and MEasurements Reports: #92 Public Radiation Exposure from Nuclear Power Generation in the United States (1987); #93 Ionizing Radiation Exposure of the Population of the United States (1987); #94 Exposure of the Population in the United States and Canada from Natural Background Radiation (1987); #95 Radiation Exposure of the U.S. population from Consumer Products and Miscellaneous Sources, (1987); and 3100 Exposure of the U.S. Population from Diagnostic Medical Radiation (1989).

Site-specific information on biological effects of radiation

List any site-specific information about radiological fundamentals below or, any concerns you have after reviewing this module.

Summary

The estimated risk associated with occupation radiation dose is similar to other routine occupational risks and much less than some risks widely accepted in society. The risk of work in a radiation environment is considered within the normal occupational risk tolerance by national and international scientific groups. However, acceptance of risk is an individual matter and is best made with accurate information. A radiological worker should understand the risk of working in a nuclear environment in relation to the risks of daily life and the risks presented by work in other professions. The intent of this module is to give you the facts about radiation exposure risks and to provide you with an opportunity to ask questions about radiation risk. It is hoped that understanding radiation risk and risk in general will help you to develop an informed and healthy respect for radiation, and that your understanding will eliminate excessive fear of or indifference to radiation.

Review Questions

1. Match the following items to the appropriate definition.

_________ Somatic effect

_________ Cell sensitivity

_________ DNA

_________ Genetic effect

a. The term used to distinguish how sensitive a cell is to radiation.

b. An effect which appears in future generations due to damage at the chromosome level.

c. Radiation effects which appear in the exposed individuals.

d. The blueprint for a cell.

2. Indicate whether the following conditions would most likely result from an acute or chronic exposure.

Vomiting ________________

Leukemia ________________

Hair loss ________________

Reddening of the skin ________________

Low red blood cell count ________________

3. List the four main categories of natural radiation.

a. ____

b. ____

c. ____

d. ____

4.Indicate whether the following sources are natural or manmade.

Radon gas ____

X-rays ____

Nuclear fallout ____

Carbon-14 ____

Bananas ____

5. Indicate the average, annual dose the general population receives from the following sources.

Cosmic ____

Terrestrial ____

Radon ____

Medical X-rays ____

6. Estimate the sensitivity level for cells of the following body tissues: high, moderate, or low.

Brain ________________

Hair follicles ________________

Bone marrow ________________

Skin ________________

Stomach lining ________________

7. If you, as a radiological worker, showed an effect from exposure to radiation, what type of an effect would this be?

____

8. If your child or grandchild showed an effect from radiation dose that you, as a radiological worker, received prior to conception, what type of effect would this be?

____

9. What are the three potential effects from prenatal exposure?

a. ____

b. ____

c. ____

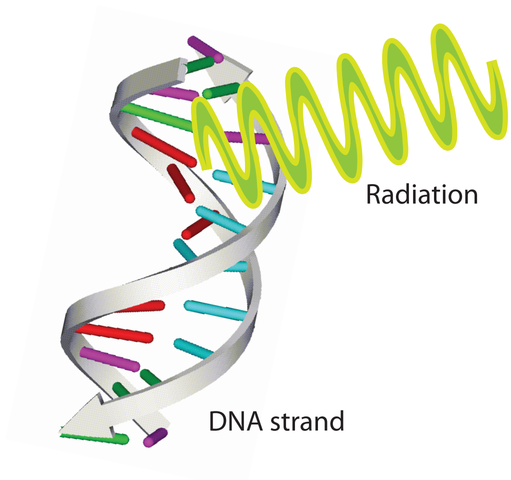
Notes:

Module 4: Radiation Dose Limits

Objectives

At the end of this module, you will have an understanding of the following:

- State the purposes of administrative control levels
- Identify the DOE radiation dose limits, DOE recommended administrative control level, and the facility/site administrative control level
- State the site policy concerning prenatal radiation exposure
- Identify the worker's responsibilities concerning radiation dose limits and administrative control levels



Purpose of the module

This module provides an introduction to the radiation dose limits set by DOE. DOE limits and administrative control levels have been established for the purpose of restricting occupational radiation exposures to levels of acceptable risk.

Objective 1: State the purposes of radiation dose limits and administrative control levels

The United States Government has established legal limits of occupational exposure in order to minimize the potential risk of biological effects associated with radiation exposure. Limits are set by regulatory agencies and cannot be exceeded intentionally, except for approved emergency actions. The established limits for occupational workers are based on guidance from the National Council on Radiation Protection (NCRP) and the International Commission on Radiological Protection (ICRP). These limits are also consistent with the “Radiation Protection Guidance to Federal Agencies for Occupational Exposure” signed by the President of the United States. DOE uses these limits, which are also consistent with those of other agencies (such as the Nuclear Regulatory Commission) and other countries.

DOE has established an Administrative Control Level (ACL) well below the legal limit to ensure employees at the various DOE facilities do not exceed the established limits. Under special circumstances and with pre-approval by DOE, the ACL may be exceeded, but additional precautions must be implemented to ensure limits are not attained.

The radiation protection standards for all DOE workers are described in 10 CFR 835, “Occupational Radiation Protection.” These regulations apply to DOE, its contractors, and persons conducting DOE activities. The regulations include equivalent dose limits.

Facility/site administrative control levels for general employees

The facility/site administrative control levels for workers are lower than the DOE limits and are set to:

- Ensure the DOE limits and control levels are not exceeded
- Help reduce individual and total worker population radiation dose (collective dose)

Objective 2: Dose Limits and Administrative Control Levels

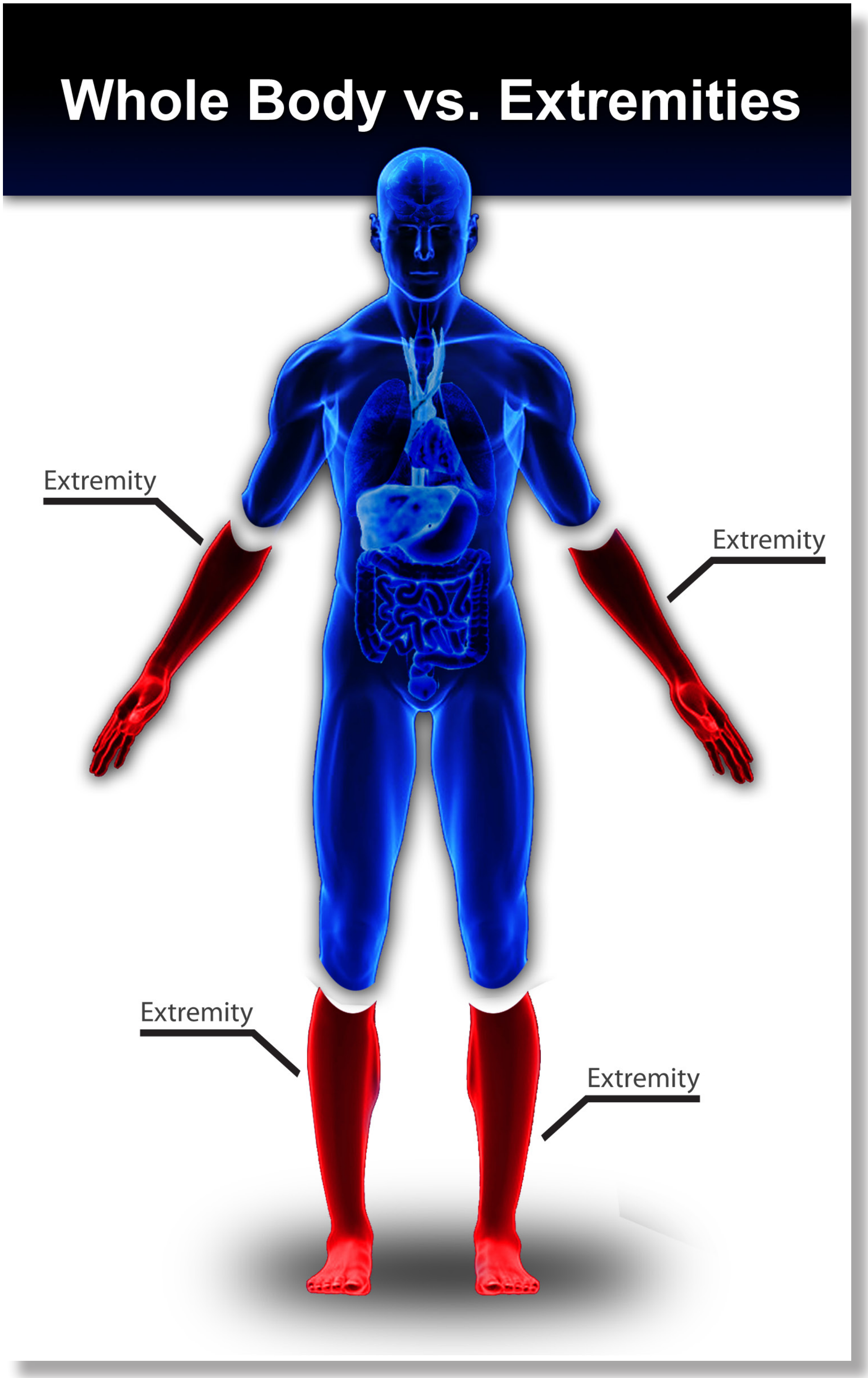
In 2007 DOE updated its models for calculating dose to use newer models recommended by international consensus groups. The impact of these changes is that some neutron exposures will be assessed differently and intakes of radioactive material will be assessed using the newer models. These models include revised terminology for some of the dosimetric terms. The following table highlights the different terms.

Table 4.1 Updated Dosimetric Terms	
Previous Dosimetric Term	DOE 2007 Amended Dosimetric Term
Committed effective dose equivalent	Committed effective dose
Committed dose equivalent	Committed equivalent dose
Cumulative total effective dose equivalent	Cumulative total effective dose
Deep dose equivalent	Equivalent dose to the whole body
Dose equivalent	Equivalent dose
Effective dose equivalent	Effective dose
Lens of the eye dose equivalent	Equivalent dose to the lens of the eye
Quality factor	Radiation weighting factor
Shallow dose equivalent	Equivalent dose to the skin or Equivalent dose to any extremity
Weighting factor	Tissue weighting factor
Total effective dose equivalent	Total effective dose

In addition to the DOE dose limits, there may be more stringent facility dose limits or facility administration control limits (ACL). There is space provided for you to write in any facility ACLs at the end of each section.

Whole body

The whole body is defined as extending from the top of the head down to just below the elbow and just below the knee. This is the location of most of the blood-producing and vital organs.



The extemeties of the body include the arms below the elbow and the legs below the knees.

Limit and control levels

There are limits for external radiation dose and there are limits for internal radiation dose. Internal dose results from radioactive material being inhaled, ingested, or absorbed through the skin or a wound.

The DOE whole body dose limit is based on the sum of internal and external dose. DOE radiation dose limit during routine conditions is 5 rem/year. Because DOE's objective is to maintain personnel radiation dose well below the regulatory limits, the DOE Radiological Control Technical Standard recommends a DOE administrative control level during routine conditions of 2 rem/year.

Facility/site administrative control level for whole body dose may be recorded in the space below.

Extremities

The definition of the extremities includes the hands and arms below the elbow, and the feet and legs below the knees.

Limit and control level

Extremities can withstand a much larger dose than the whole body because there are no major blood-producing organs located in these areas of the body. DOE radiation dose limit for extremities is 50 rem/year.

Facility/site administrative control levels for extremities may be recorded in the space below.

Skin and other organs

DOE radiation dose limit for skin and other organs is 50 rem/year.

Record facility/site administrative control level for skin and other organs in the space provided below.

Lens of the eye

DOE radiation dose limit for lens of the eye is 15 rem/year.

Record facility/site-specific dose to the lens of the eye information in the space provided below.

Objective 3: Declared pregnant worker: embryo/fetus

After a female worker voluntarily notifies her employer in writing that she is pregnant, she is considered a declared pregnant worker. For the purposes of radiological protection of the embryo /fetus, DOE requires a special limit for dose to the embryo/fetus. In addition, the DOE RCS recommends that the employer provide the option of a mutually agreeable assignment of work tasks, with no loss of pay or promotional opportunity, such that further occupational radiation exposure is unlikely during the remaining gestation period. This declaration may be revoked, in writing, at anytime by the declared pregnant worker.

DOE dose limit for a declared pregnant worker who continues working as a radiological worker (during the entire gestation period) is 500 mrem. Measures shall be taken to avoid substantial variation above the uniform exposure rate necessary to meet the 500 mrem limit for the gestation period. The DOE RCS recommends that efforts be made to avoid exceeding 50 mrem/month to the embryo/fetus of the declared pregnant worker. If the dose to the embryo/fetus is determined to have already exceeded 500 mrem when a worker notifies her employer of her pregnancy, the worker shall not be assigned to tasks where additional occupational radiation exposure is likely during the remainder of the pregnancy.

Enter specific site policy and facility/site administrative control levels for declared pregnant workers below.

Members of the public and occupationally exposed minors

DOE radiation dose limit is 100 mrem/year (0.100rem/year). There is an additional limit for occupationally exposed minors of 10% of the other limits. Enter facility/site administrative control levels for members of the public in the space provided below.

Table 4.2 summarizes the DOE dose limits and ACL control levels. There is also space for you to write in Facility ACL's for where you work. These limits and control levels are important! It would benefit you greatly if you would commit these to memory as they will better help you understand how to protect yourself, comprehend radiation measurements and allow you to act accordingly during radiation emergencies.

Table 4.2: Summary of radiation dose limits and control levels

Type of dose	DOE dose limit (rem/year)	DOE recommendation (rem/year)	Facility ACL (enter in space below)
Whole Body	5	2	
Extremities	50	N/A	
Skin and other organs	50	N/A	
Lens of the eye	15	N/A	
Declared pregnant worker	50 mrem/month. Max 500 mrem/gestation period	N/A	
Members of the public	0.1	N/A	
Occupational exposed	0.1 whole body	N/A	
Minors	and 10% of other above limits		

The chart is based on limits and control levels for routine conditions. The limits and control levels are also based on the sum of internal and external dose. 1.) External dose is from sources outside the body. Internal dose is from sources inside the body. 2) The internal dose reported in a given calendar year is actually the projected dose the individual will receive over the next 50 years from intakes in that calendar year. Radioactive material may be inhaled, ingested, or absorbed through the skin or an open wound.

Objective 4: Identify the worker's responsibilities concerning radiation dose limits and administrative control levels

It is each worker's responsibility to comply with DOE dose limits and facility/site administrative control levels. If you suspect that dose limits or administrative control levels are being approached or exceeded, you should notify your supervisor immediately.

Record facility/site-specific information on worker's responsibilities in the space provided below.

Review Questions

1. What is the purpose of the facility administrative control levels?

____

____

2. What are the DOE radiation dose limits for the following:

Whole body: ___________________________

Eyes: ___________________________________

Skin: ___________________________________

Extremities: ____________________________

3. What is the site policy for prenatal radiation exposure?

____

____

____

4. As you approach your radiation dose limits, who should you notify?

____

Notes:

Module 5: ALARA Program

Radiological excavation. Hanford site. Courtesy DOE.

Objectives

At the end of this module, you will be able to select the correct response from a group of responses to verify your ability to:

- State the ALARA concept
- Explain how ALARA differs from classic IH practices
- State the DOE policy for the ALARA program
- Identify the responsibilities of management, the Radiological Control Organization, and the radiological worker in the ALARA program
- Identify methods for reducing external and internal radiation dose
- State the pathways by which radioactive material can enter the body
- Identify methods a radiological worker can use to minimize radioactive waste

Purpose of the module

This module's primary goal is to review the ALARA concept and contrast it to the principle approach to managing chemical exposures under industrial hygiene. These materials closely follow the main DOE handbook on Radworker II training (DOE-HDBK-1130-2007, December 2007).

Objective 1: State the ALARA concept

Let's be sure we know this abbreviation. Fill in the chart below.

Letter	*Word*
A	
L	
A	
R	
A	

What are the broad concepts?

- Some risk exists from any radiation dose, so exposure should be kept ALARA.
- ALARA includes reducing both the internal and external radiation dose.
- ALARA is an integral part of all DOE site activities that involve sources of ionizing radiation.

Objective 2: Explain how ALARA differs from classic IH practices

What is the difference between the OSHA health standards and the ALARA concept?

Does OSHA have a radiation standard? Write your answers below.

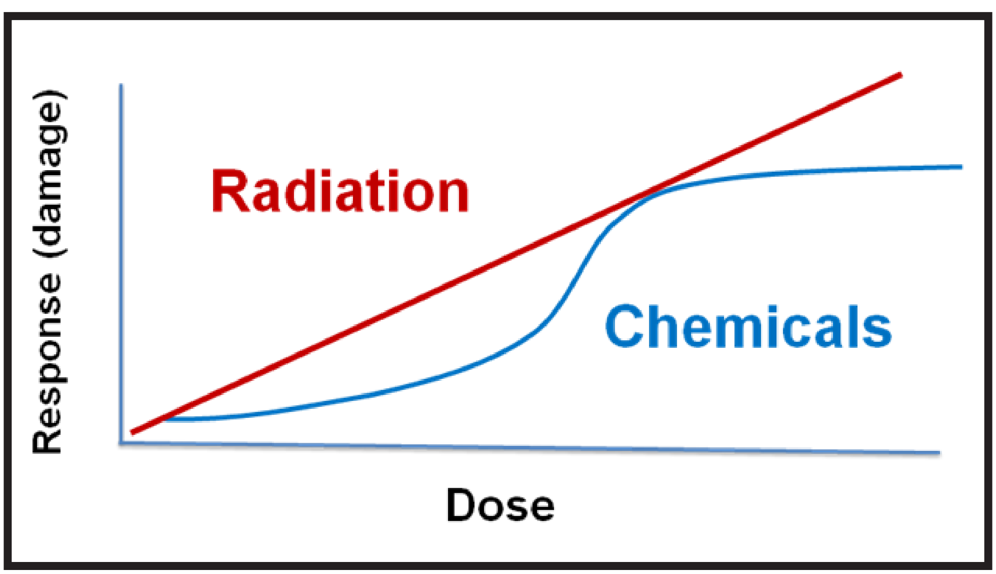
The OSHA health standards are based on the concept that there is a limit below which workers should not have appreciable health effects. These occupational exposure limits are called Permissible Exposure Limits and represent the regulatory threshold for employers. Going over the limit (as an 8-hour, time-weighted average) opens an employer to citations, but OSHA does not include ALARA in their approach.

There is an OSHA standard for radiation. It is 29 CFR 1910.1096, “Ionizing Radiation” and it does not mention ALARA. There is an OSHA construction standard for radiation, 1926.53, but it isn’t nearly as specific as the general industry.

Here it is in its entirety:

> *1926.53(a): In construction and related activities involving the use of sources of ionizing radiation, the pertinent provisions of the Nuclear Regulatory Commission Standards for Protection Against Radiation (10 CFR Part 20), relating to protection against occupational radiation exposure, shall apply.*
>
> *1926.53(b): Any activity which involves the use of radioactive materials or x-rays, whether or not under license from the Nuclear Regulatory Commission, shall be performed by competent persons specially trained in the proper and safe operation of such equipment. In the case of materials used under Commission license, only persons actually licensed, or competent persons under direction and supervision of the licensee, shall perform such work.*

The basic assumptions for chemicals and radiation are different.



OSHA has established 8-hour, time-weighted averages for most chemicals because we can be exposed to most chemicals in low doses without showing any effect. In the graph, that is the initial blue line that stays fairly level while the dose increases. Then the body cannot handle the exposure and symptoms often begin and continue to worsen. Think about increasing exposures to a solvent that causes light-headedness, but can lead to loss of balance and then coma and death. Radiation is different in that it causes chromosomal damage at even low levels. Any exposure carries risk.

Objective 3: State the DOE policy for the ALARA program

ALARA is a process, not a dose limit!

ALARA should not be confused with a Permissible Exposure Limit (PEL) or Threshold Limit Value (TLV). ALARA is a process of thinking about every aspect of a project that involves radiation exposure to determine how that exposure can be reduced.

Here is a real example from T Plant in Hanford, Washington. A specially-trained team at the plant treated the first radioactive sludge to be removed from the K Basins. Treatment consisted of mixing small amounts of the liquid sludge with a special cement called grout, and allowing the grout to dry and harden, immobilizing the sludge. The mixing occurred inside 55-gallon drums, staged inside a shielded station installed on the deck of the T Plant. **All** steps of the transportation, mixing and drying processes were conducted under controlled ALARA conditions to minimize radiation dose to workers and ensure that only small, measured amounts of sludge are moved and handled at any given time.

Hanford technicians treating radioactive sludge at T Plant. Photo courtesy DOE.

The ALARA concept underpins all DOE radiological programs.

The concept incorporates these three principles:

1. Personal radiation exposure maintained ALARA.
2. Radiation doses are well below regulatory limits.
3. There is no radiation exposure without an overall benefit.

Here is the exact quote from DOE:

> **"There should not be any occupational exposure of workers to ionizing radiation without the expectation of an overall benefit from the activity causing the exposure."** *DOE Radiological Control Manual*

Objective 4: Identify the responsibilities of management, the Radiological Control Organization, and the radiological worker in the ALARA program

ALARA is everyone's responsibility.

- Workers
- Management
- Radiological Control Organization
- ALARA Committee, if the site has one

Surveying for buried fuel elements during Interim Safe Storage, F Reactor at Hanford. Photo courtesy of DOE.

Management is responsible for several key ALARA aspects, which include:

- Making a firm commitment to the program
- Ensuring that workers are trained to the appropriate level
- Ensuring work is thoroughly planned
- Ensuring PPE is available and worn as intended

Check the specifics of your site's ALARA plan because DOE requires that each site have its own program.

The Radiological Control Organization implements the ALARA program at your site.

The Radiological Control Organization is responsible for implementing the ALARA program at the Site. It is also responsible for implementing the requirements for the entire Radiological Control program. These requirements are established in DOE Orders, the DOE Radiological Control Manual, and Site Radiological Control documents.

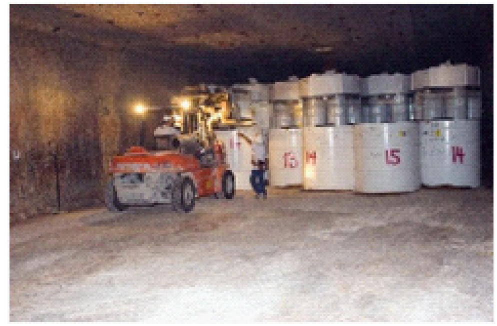
A radiation technician monitors a tank for contamination before it is cut up for disposal. April 26, 1994, Fernald, OH . Courtesy of DOE.

Radiological Control Technicians (RCTs) are your points of contact for the ALARA program.

RCTs can interpret sampling results and help with PPE issues. They should be asked any questions about work assignments.

Each radiological worker is expected to demonstrate responsibility and accountability.

DOE indicates that responsibility and accountability are accomplished through an "informed, disciplined and cautious attitude toward radiation and radioactivity."

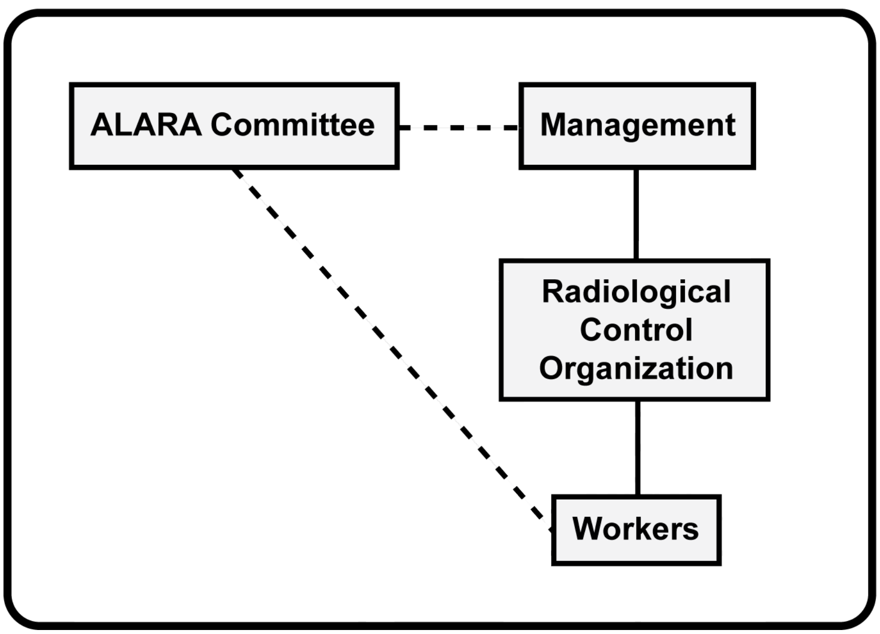


Waste Handling Technicians placing Transuranic (TRU) waste approximately a half mile underground at the Waste Isolation Pilot Plant, Aug 31, 2005. Carlsbad, NM.

An ALARA committee can keep the program focused.

- It should be comprised of both managers and workers from the line
- It can serve as a technical support organization
- It must have input to the Radiological Control Organization
- It should make recommendations to management on minimizing exposure and releases

Common Reporting Structure With ALARA Program



This image shows a typical organizational structure for sites with an ALARA program in place. The ALARA committee often reports to management while being allowed enough independence to be seen as a fair arbiter. This structure may be different from site to site.

Objective 5: Identify methods for reducing the external and internal radiation dose

The hierarchy of controls is part of ALARA

Remember: Moving from left to right increases the amount of responsibility placed on workers to ensure their own protection, consequently, the risks increase.

Can you give examples of radiation control at each level?

In your groups, discuss examples of radiation controls for each level of the hierarchy of controls. Write at least one example for each below.

Level	*Hierarchy*	*Examples*
1	Elimination/substitution	
2	Engineering	
3	Administrative	
4	PPE	

- Engineering controls should be the primary method to control exposure (e.g., enclosed hoods).
- Administrative controls are the next method to control exposures (e.g., postings).
- Personnel protective equipment is the last method (e.g., respirators).

Group Exercise: What are the 3 key ALARA practices to reduce dose? Give examples.

There are three major practices to reduce dose that should be considered for each project. In your group discuss the three ALARA practices and record them. Write two examples of each practice below.

1.	**2.**	**3.**
Example 1:	Example 1:	Example 1:
Example 2:	Example 2:	Example 2:

DOSE = Dose rate x time

Dose is based on a dose rate over a period of time.

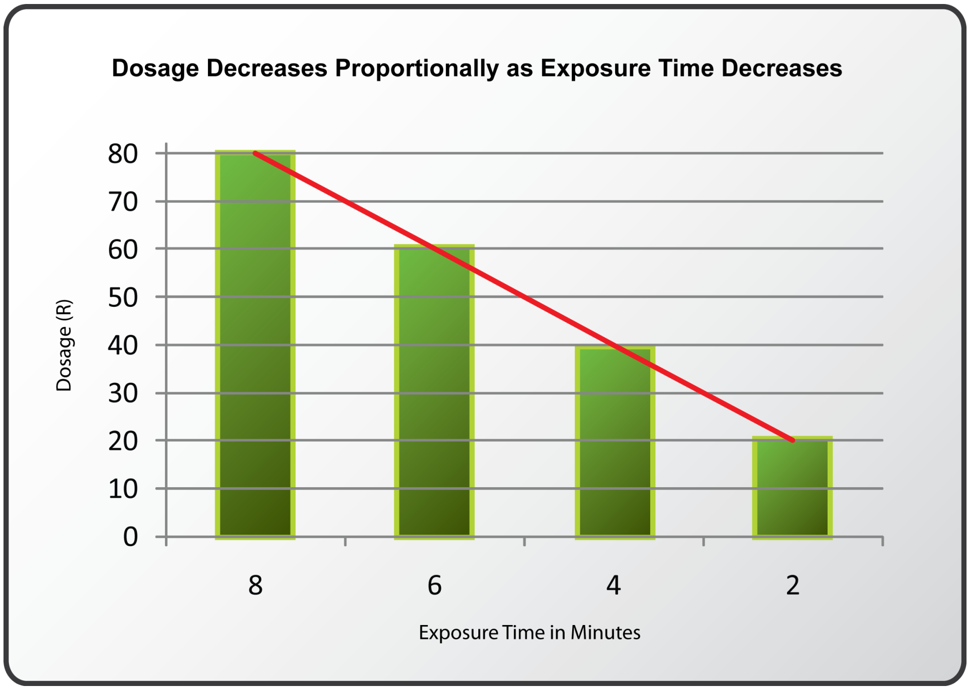
Photo courtesy DOE, Aug 16, 2004. Hanford Site, Richland, WA.

Reducing the time spent in a field of radiation will lower the dose.

This Health Physics Technician (HPT) demonstrates how dose readings used to be taken. He designed a stand or "Jig" (shown in insert) that allows the instrument to stabilize without the HPT holding it. This allows the HPT to keep dose ALARA, and avoid potential back strain.

Minimizing time takes planning.
Consider taking the following actions:

1. Plan and discuss the task thoroughly before entry.
2. Use only the number of workers needed for the job.
3. Have all necessary tools present before entry.
4. Use mock-ups and practice runs that duplicate work conditions. Mock-up should be as realistic as possible.
5. Take the most direct route to the job site.
6. Never loiter in a radiologically-controlled area.
7. Work efficiently and swiftly.
8. Do the job right the first time.
9. Perform as much work outside the area as possible.
10. When practical, remove parts or components to areas with lower dose rates to perform work.
11. Do not exceed stay times. In some cases, the Radiological Control Organization may limit the amount of time a worker may stay in an area due to various reasons. This is known as "stay time." If you have been assigned a stay time, do not exceed it.



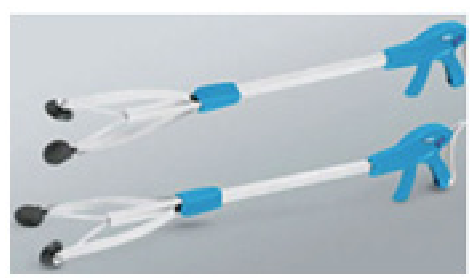

July 31, 2001. Fernald Closure Project, Fernald, OH. Courtesy of DOE.

Stay times can be set for heat, as well as radiation.

This is an image of an industrial hygienist radioing temperature and humidity information to safety personnel. The safety personnel use the measurements to determine stay times to avoid worker heat stress.

Distance is the second tool for reducing dose.

These are grabbing tools that were used at Savannah River to handle the ceramic reducer of a centrifugal pump that pumped highly radioactive slurry at Savannah River.

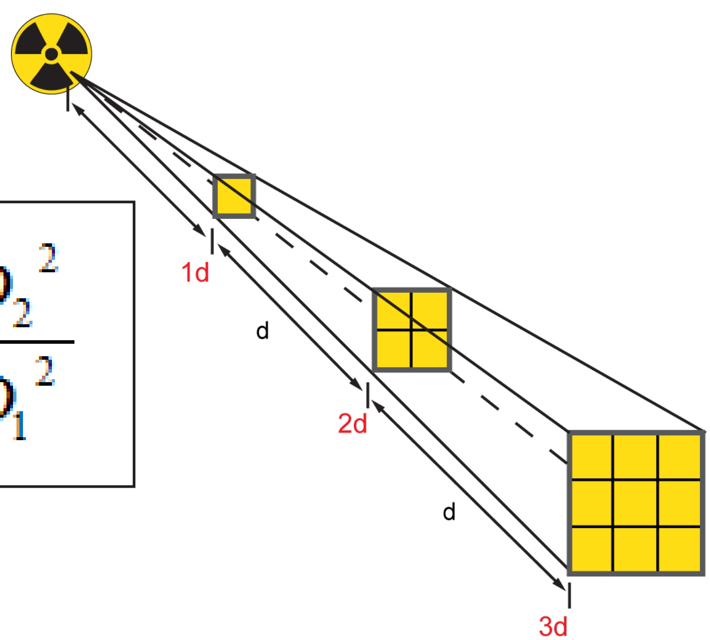

Grabber tools used at the Savannah River site.

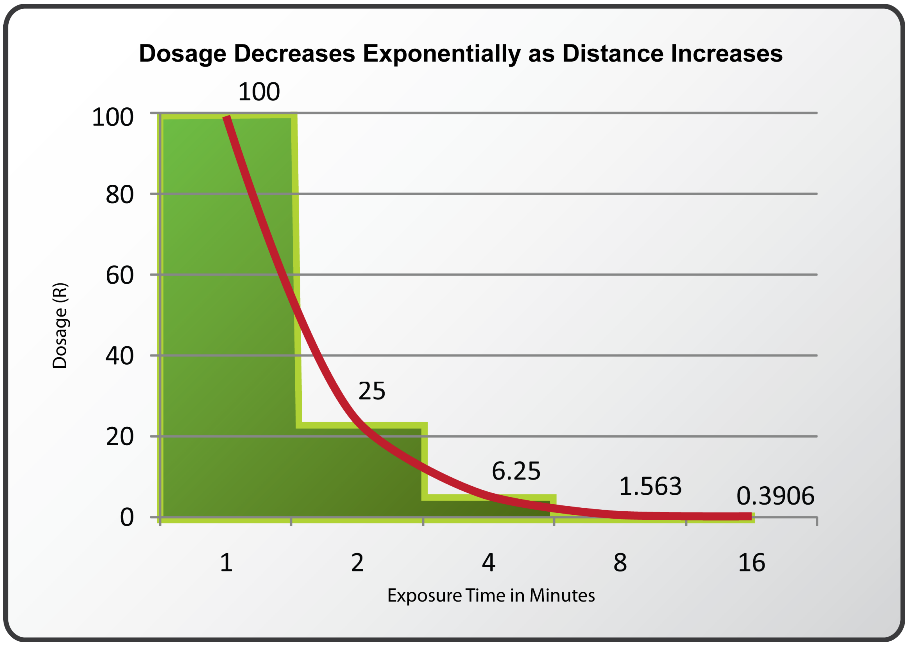
Why does extending the work by such a seemingly small amount make a difference?

What is the inverse square law?

According to the inverse square law, radiation spreads out as it travels away from the radiation source. The intensity is inversely proportional to the distance from the source. In other words, using the inverse square will allow you to determine radiation intensity at a new distance, if you know the old intensity and old distance. The following formula demonstrates the inverse square law where the source intensity (I_1) from at least one distance (D_1) has been determined:

$$\frac{I_1}{I_2} = \frac{{D_2}^2}{{D_1}^2}$$





Inverse square law exercise

Fill in the missing information

0 ft.	1 ft.	2 ft.	3 ft.	4 ft.
	• 1 • 100 mrem/hr	• 1/4 • 25 mrem/hr	• ______ • 11 mrem/hr	• 1/16 • ______ mrem/hr

Inverse square law exercise answers

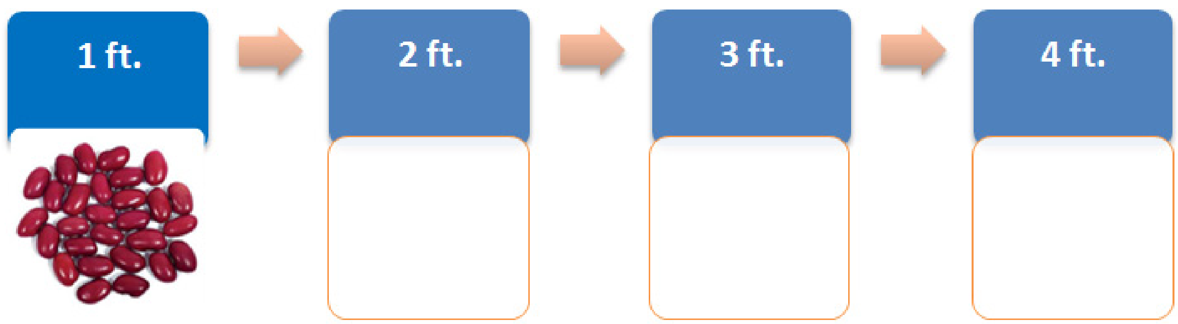
0 ft.	1 ft.	2 ft.	3 ft.	4 ft.
	• 1 • 100 mrem/hr	• 1/4 • 25 mrem/hr	• 1/9 • 11 mrem/hr	• 1/16 • 6 mrem/hr

Bean smart with distance: inverse square table top exercise

Instructions. In your group:

1. Place an “X” for the on the table for the rad source
2. Place 20 beans in a pile 1 foot away, each is a mrem
3. Measure 2 feet away and put the number of beans that would be left.
4. Do the same for 3’ and 4’ from the pile.

Write the numbers below.



Distance is a powerful tool; use it.

- Stay as far away from radiation sources as practical.
- Be familiar with radiological conditions in the area.
- During work delays, move to lower dose rate areas.
- Use remote handling devices.

Shielding reduces the amount of radiation dose to the worker.

Shielding reduces the amount of radiation dose to the worker, but material matters.

The 233-S Plutonium Concentration Facility, that operated from 1956 to 1964, was the first plutonium facility to be torn down at Hanford. The outer rooms were removed in the first phase from October to December 2003. The second phase is focusing on the inner concrete structure, that consists of a containment area with concrete shielding walls up to a foot thick. The roof and walls of the inner structure are being cut into pieces and lifted into large containers, which will be transported to Hanford's Environmental Restoration Disposal Facility.

Foot thick concrete shielding being removed during demo of Plutonium Concentration Facility, Hanford, 2004. Courtesy of DOE.

Shielding material must be matched to the radiation source

Shielding reduces the amount of radiation dose to the worker, but material matters. It is important to choose the right material based on the type of exposures. Lead bricks are routinely used for shielding from x-rays in radiochemistry labs and other workplaces.

Lead bricks, Photo courtesy Wikimedia.

Lexan shields lower extremity doses from beta radiation

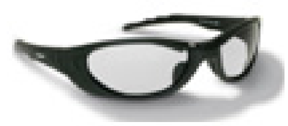
Extension rod with beta shield. Courtesy Fermilab.

Pressure washer with beta shield. Courtesy Fermilab.

Radiation exposures are set differently for extremities, like the hands. Shielding can lower the doses. The devices shown above were designed to unclog lines that contained highly radioactive sludge. The pressure washer worked very well.

Shielding guidance from DOE

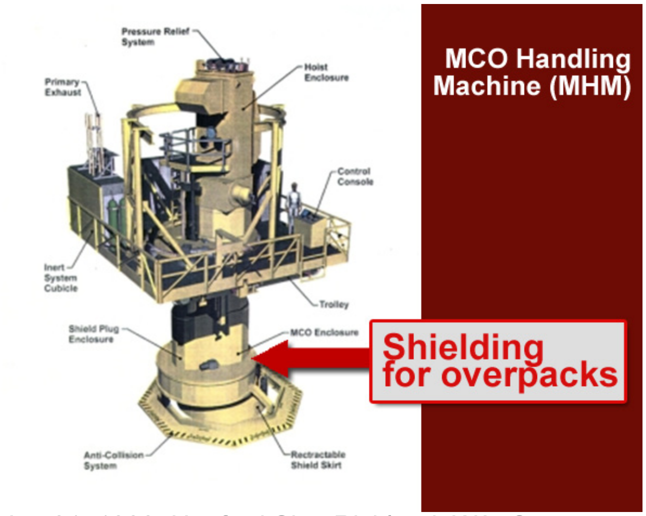
1. Take advantage of permanent shielding, such as non-radiological equipment and structures.
2. Use shielded containments when available.
3. Wear safety glasses/goggles to protect your eyes from beta radiation.



Leaded-glass safety glasses, Photo courtesy Medical Safety Glasses.

Temporary shielding guidance from DOE

1. Temporary shielding can only be installed when proper procedures are used.
2. Temporary shielding will be labeled with wording such as “Temporary Shielding - Do Not Remove Without Permission from Radiological Control”.
3. Once temporary shielding is installed, it cannot be removed without proper authorization.



Jan 31, 1999. Hanford Site, Richland, WA. Courtesy DOE.

Equipment can be shielded.

This large gantry crane at Hanford has a permanently attached, moveable cask for shielding Multi Canister Overpacks (MCO) and transferring them safely for storage.

Image courtesy Department of Energy.

Shielding inside a glove box is ALARA.

Rocky Flats - New Shielding Equipment (ALARA) inside a glove box in Building 559

Photo Date: June 9, 1999
Rocky Flats Environmental Technology Site, Golden, CO

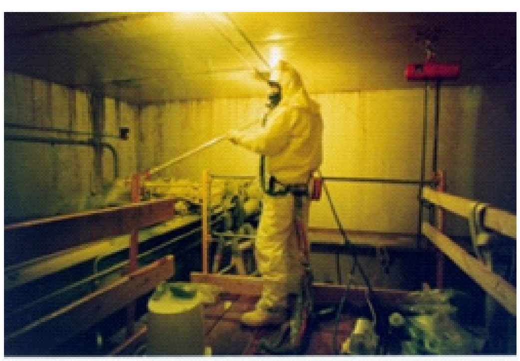


Image courtesy Department of Energy.

Fixative spray paint applied as an "ALARA coat" is shielding.

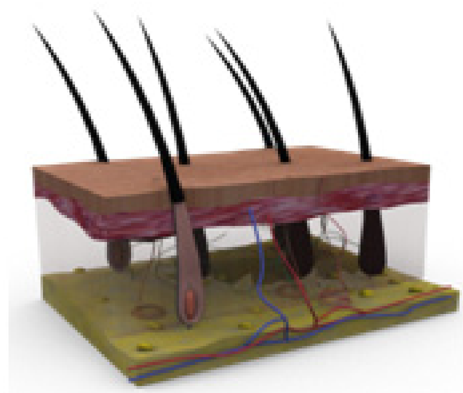
West Valley - Fixative spray paint used in D&D, Environmental Management West Valley Demonstration Project, West Valley, NY.

Source reduction is another way to reduce dose.

Source reduction often involves procedures such as flushing radioactive systems, decontamination, and removal of contaminated items. This is done to reduce the amount of radioactive materials present in/on a system because these materials can add to radiation levels in an area.

What level of the hierarchy of controls does this represent? Write your answer in the box below.

Objective 6: State the pathways by which radioactive material can enter the body



Representation of a cross-section of skin.

How do radioactive materials get into the body?

- Inhalation
- Ingestion
- Absorption through the skin
- Absorption through wounds

What is the most significant route? Why are wounds of concern?

Scientists in a radioactive environment don PPE to reduce their exposure to the source.

Internal exposure can be prevented with PPE.

What kind of respirators are the RCTs using to measure the radiation levels? Write your answer in the box below.

But PPE is the last choice for controlling internal exposures.

1. Wear respirators properly when required. Respirators should only be used by personnel qualified to wear them.
2. Report all wounds or cuts (including scratches and scabs) to the appropriate facility/site-specific organization before entering any area controlled for radiological purposes.
3. Comply with the requirements of the radiological control documents.
4. Do not eat, drink, smoke, or chew in Radioactive Materials Areas, Contamination Areas, High Contamination Areas, or Airborne Radioactivity Areas, as dispersible radioactive materials may be present.

Objective 7: Identify the methods a radiological worker can use to minimize radioactive waste

What are some of the rad wastes generated by our work?

One of the potential consequences of working with radioactive materials is the generation of radioactive waste. Procedures must be in place to properly dispose of radioactive waste. Examples of radioactive waste include:

- Paper
- Gloves
- Glassware
- Rags
- Brooms
- Mops

The ALARA concept also applies to minimizing radioactive waste. This will reduce personnel exposure associated with the handling, packaging, storing, and disposing of radioactive waste. This will also reduce the resultant costs. It is very important for each worker to minimize the creation of radioactive waste.

Minimize the materials used for rad work.

1. Take only the tools and materials you need for the job into radiological areas.
2. Unpack equipment and tools in a clean area.
3. Use tools and equipment identified for radiological work.
4. Use only the materials required to clean the area.
5. Use plastic to sleeve or cover clean materials brought into contaminated areas.

Separate radioactive waste from non-radioactive waste.

1. Place radioactive waste in the containers identified for radioactive waste. Do not place radioactive waste in non-radioactive waste containers.
2. Do not throw non-radioactive waste, or radioactive material that may be reused, into radioactive waste containers.
3. Use good housekeeping techniques.
4. Separate compactable material from non-compactable material.
5. Minimize the generation of mixed waste. Mixed waste is waste that contains both radioactive and hazardous materials.

ALARA waste separation case study.

Waste separation glove boxes.

Bag-out station.

In 2006, Savannah River National Laboratory safely remediated 240 waste drums containing rad waste. The drums had originally been packed with items that were prohibited at the Waste Isolation Pilot Plant (WIPP) so the drums needed to be inspected and to have their materials segregated. Acceptable items could then be sent to WIPP. Even though this was a temporary job, they applied a permanent approach and set up glove boxes to separate waste as an ALARA strategy. The team traveled to other sites first to see how it was done elsewhere. A solid wall and confinement zone were used to separate the higher radiation drumming stations (higher risk hazard) from the sorting operations. Photos courtesy of Savannah River

ALARA excavation case study

This excavation was performed to deal with leaking underground transfer lines with highly radioactive sludge. A work package was developed to reduce the dose by installing a containment hut with portable HEPA units, including an air conditioning system due to the high temperatures.

Excavation of leaky underground transfer lines carrying radioactive sludge.

Bonus question: What is the significance of a frog in a rad class?

Frogs affected by ORNL waste ponds.

Tiny amphibians had been feeding and breeding in ORNL's waste ponds. As a result, they were acquiring low levels of radiation. The problem got worse when workers installed wire nets over the ponds to keep geese from nesting there. But the nets also kept the herons away. The herons had been eating the little leopard frogs. Soon, the local food chain got out of whack and hot little frogs were getting run over by cars and showing up in places they wouldn't ordinarily be found. And, with ORNL being a nuclear facility, the radioactivity got detected, measured, and reported in a lab bulletin.

List any site-specific ALARA Program information you have experienced in the box below.

Review Questions

1. DOE radiation ALARA policy applies to: (Check all those that apply.)
a. ___ Radiation exposures.
b. ___ Contamination exposures.
c. ___ Asbestos exposures.
d. ___ Cosmic radiation exposures.
e. ___ Chemical exposures.
f. ___ Medical X-Rays.

2. DOE Management policy is designed to keep radiation doses well below regulatory limits and that there is no occupational radiation dose without

_________________________.

3. Who provides a point of contact for the workers to obtain the most current radiological conditions in an area?

____

4. The basic protective measures for ALARA are: (Check all that apply.)
a. ___ Maximizing time in an area.
b. ___ Minimizing time in an area.
c. ___ Maximizing distance in an area.
d. ___ Minimizing distance in an area.
e. ___ Maximizing shielding in an area.
f. ___ Minimizing shielding in an area.

5. List five methods to reduce the amount of time spent in a radiation area.

a. ____

b. ____

c. ____

d. ____

e. ____

6. Which of the following are pathways radioactive material may enter the body?
a. ___ Chewing gum in a contamination area.
b. ___ Entering a radiation area without proper dosimetry.
c. ___ Entering radiological areas.
d. ___ Not wearing a respirator when required by procedure.
e. ___ Receiving an x-ray from medical.
f. ___ Working with radioactive materials that can be absorbed through the skin without protective equipment.

7. Radioactive waste can be minimized by: (Check all that apply.)
a. ___ Minimize materials used for radiological work.
b. ___ Separate radioactive waste from nonradioactive waste
c. ___ Use only tools and materials required in radiological areas.
d. ___ Minimize mixed waste.

Notes:

Module 6: Personal Monitoring Programs

Objectives


Personal radiological monitoring equipment.

At the end of this module, you will have an understanding of the following:

- State the purpose and worker responsibilities for each of the external dosimeter devices used at the site
- State the purpose and worker responsibilities for each type of internal monitoring method used at the site
- State the methods for obtaining radiation dose records
- Identify worker responsibilities for reporting radiation dose received from other sites and from medical applications

Purpose of the module

This module provides an introduction to the different types of personal monitoring devices used to determine your dose to radiation. This module will help workers identify the purpose, types, and worker responsibilities for each type of personnel monitoring program, as outlined in this module.

Each employee's external and internal dose to ionizing radiation is assessed using special types of monitoring equipment. The types of equipment used depend on the radiological conditions present. Because different conditions and exposures exist at different facilities, the types of monitoring equipment (dosimetry) may be different at different sites. Also, different sites may use different names for certain types of monitoring equipment.

Objective 1: State the purpose and worker responsibilities for each of the external dosimeter devices used at the site

One method that reduces your risk of suffering harm from radiation is using a personal dosimeter and following the procedure outlined in your site's personnel dosimetry program. The following section will outline different types of personal dosimetry products, what they do and what your responsibilities are under a personnel dosimetry program.

External dosimetry

A dosimeter is a device that measures radiation dose. Dosimeters used to measure external sources of radiation are called external dosimeters. In this module we discuss the purpose of each of the external dosimeter devices used (including basic principles of operation of the types commonly used at the site).

List the types of external dosimetry used at your site in the space provided below:

Worker responsibilities for external dosimetry include the following:

Wear dosimeters at all times in areas controlled for radiological purposes, when required by radiological signs, radiological work permits or Radiological Control personnel. Primary dosimeters are worn on the chest area, between the waist and the neck in a manner directed by Radiological Control personnel.

Wear supplemental dosimeters (e.g., pocket, electronic, neutron) when required, in accordance with site policy.

Take proper actions if dosimeter is lost, off-scale, damaged or contaminated while in an area controlled for radiological purposes. These actions can be remembered by using the mnemonic "PAIN." The actions include:

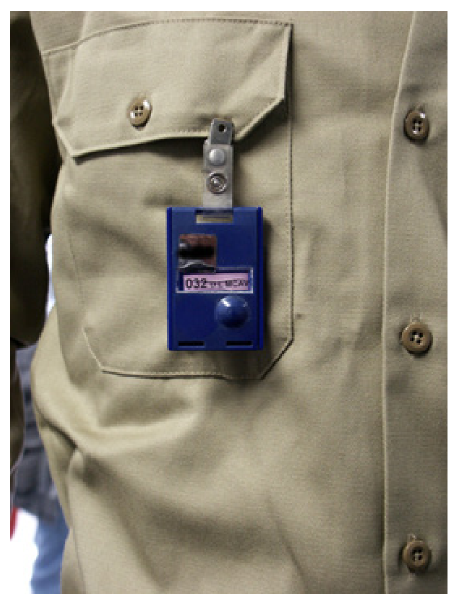
- Place work activities in a safe condition
- Alert others
- Immediately exit the area
- Notify Radiological Control personnel

Know the proper dosimeter storage location and return dosimeters for processing periodically. Personnel that fail to return dosimeters will be restricted from continued radiological work. Dosimeters issued from the permanent work site cannot be worn at another site.

Thermoluminescent Dosimeter (TLD)

Purpose: The thermoluminescent dosimeter (TLD) is a badge that the worker wears, usually clipped to the shirt pocket, or to a strap on the worker's anti-Cs. There are TLDs that measure Beta, Gamma and neutron radiation exposure. On a regular schedule (monthly or quarterly, for example) the TLD is sent to the laboratory to be read. The results of the TLD readings are maintained by the facility as the legal record of the worker's occupational radiation exposure.

Principle of operation: Inside its plastic case, the TLD contains special crystals that absorb energy from ionizing radiation. This energy causes electrons in the crystals to move to a higher orbit. Later, in the dosimetry laboratory, the TLD is placed in a processor that heats the crystals. When the crystals are heated, they give off a small amount of light as the electrons drop back to their normal orbit. The more radiation the TLD absorbed, the more light the crystals release. The processor measures this light and determines the radiation dose.



Proper placement of docimeter badge.

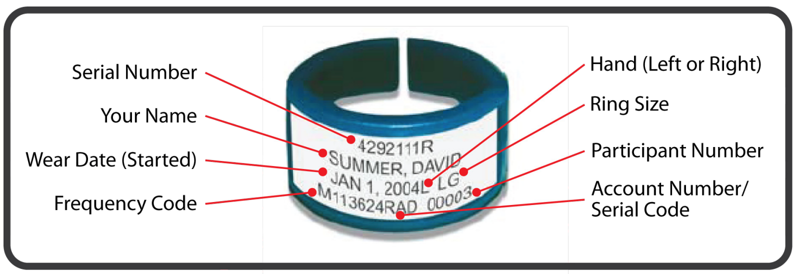
Proper use: Because the TLD is used to establish the legal record of your radiation exposure, it is important that you wear it at all required times, and that you wear it properly. It should be worn in front, between your neck and your waist. Make certain that the front of the TLD is facing out. There is usually a rack in which you place your TLD when you leave the area in which it is required. Generally, you should not take the TLD home at the end of your shift!

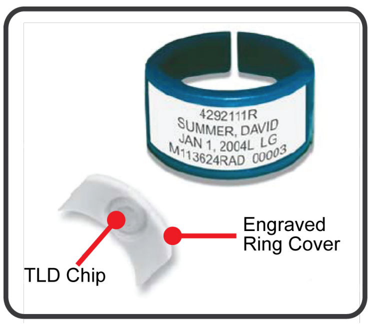
Finger ring

Purpose: This dosimeter measures radiation dose to the hands. This information is also recorded as part of the legal record of your radiation exposure.

Principle of operation: The ring dosimeter has the same type of crystals used in regular TLDs. It is read in the laboratory in the same manner.

Proper use: A finger ring is worn on any finger except the thumb, with the TLD chip facing the radiation source. Often this means that the chip faces the palm of the hand, in order to measure exposure from materials that the worker handles. If the source of exposure is located above the worker's hands, then the TLD chip should face outward. An example of a finger ring and its components is shown below:



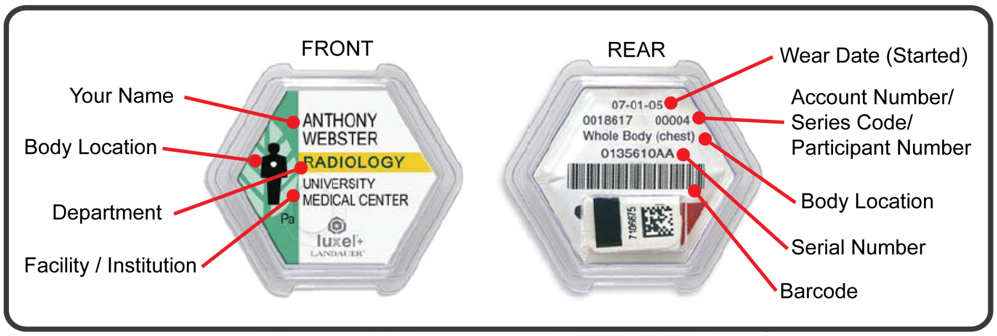


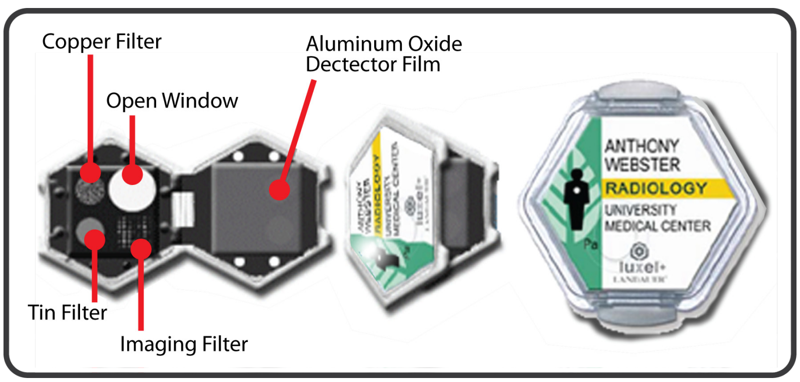
Film badge

Purpose: Film badges can be used to measure exposure to Gamma and X-rays, as well as Beta and neutron particles.

Principle of operation: The film badge contains photographic film, and one or more filters. If the film is exposed to ionizing radiation, it darkens. On a regular schedule the badge is opened in the laboratory and the film is developed. The darker the film, the greater the radiation exposure that is indicated. The filters affect how much radiation gets to certain parts of the film. Higher energy radiation (Gamma, X-ray, and neutron) can penetrate the filters more easily than lower energy radiation (Beta). The darkness of different parts of the film indicates the pentration level of the radiation.

Proper use: Film badges can be damaged by heat, light and moisture. Don't leave the badge anywhere that the temperature gets above 124˚F. If the case of the badge is torn or punctured, light will enter and ruin the film. Don't let the badge get soaking wet. An example of a film badge and its components is shown below:





Self reading Pocket Dosimeter

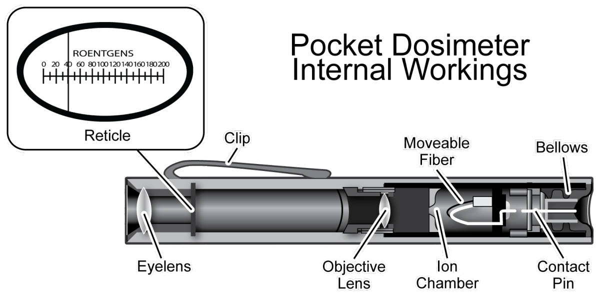
This dosimeter has several different names:

- Self reading pocket dosimeter (SRPD)
- Direct reading dosimeter (DRD)
- Pocket ionization chamber (PIC)
- Quartz fiber dosimeter

Example of self reading Pocket Dosimeter.

Purpose: This dosimeter measures Gamma and X-ray exposure. The worker can read this dosimeter at any time. It does not have to be sent to the laboratory to be read. It provides an immediate, on the spot estimate of radiation exposure.

Principle of operation: The dosimeter contains two tiny quartz fibers. Before the dosimeter is issued to a worker, it is charged (zeroed) with a charging device (see photo below) that uses a small electric charge that causes the fibers to separate. When the fibers are exposed to Gamma or X-ray radiation, the charge is reduced, and the fibers move closer together. The amount the fiber moves is directly proportional to the amount of ionization which occurs. To read the dosimeter, hold it up to the light. You will see a line across the numbered scale. That line is actually one of the fibers. Where the line appears on the scale indicates how much radiation has been absorbed.



Pocket docimeter cross-section.

Proper use: Wear this dosimeter near your TLD. Read it before you begin the job assignment, regularly during the job, and at the end of your work. In a high radiation area, read the dosimeter at least once every 10 minutes. The radiological work permit (RWP) may require more frequent reading. Don't drop or bang the dosimeter. This can change the reading. If the reading rises sharply or goes off scale, or if you damage or lose the dosimeter, follow the "PAIN" procedure indicated previously in the Worker Responsibilities section.

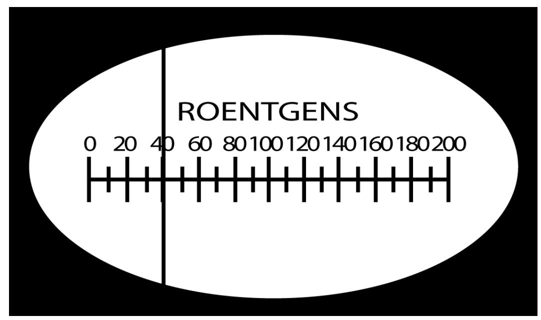
At periodic intervals, you will need to charge you Pocket Dosimeter so that the scale will be set to zero. Your sites Health Physicist or Radiological Control Officer will let you know when the device should be charged. As rule of thumb, the Pocket Dosimeter should be charged when the scale reaches one half of its capacity, although check with your RWP for details.

Example Pocket Dosimeter charging station.

Activity 6.1: reading pocket dosimeter

Pocket dosimeter

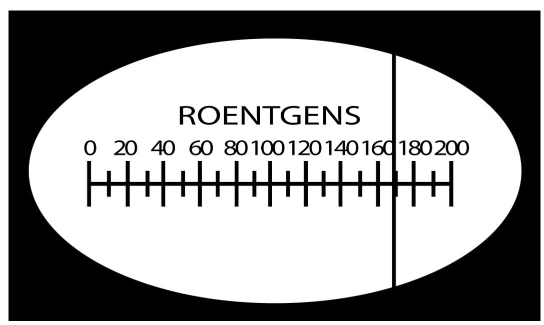
The quartz fiber pocket dosimeter is a precision instrument that measures the cumulative exposure to X-ray and Gamma radiation received by the wearer. The instrument consists of an ionization chamber, a quartz fiber electrometer, a precision integrating capacitor, and a microscope, all contained within a sealed barrel. A scale, calibrated in Roentgens (R), may be read by looking through the eyepiece toward a source of light. The dosimeter is reset to zero with an auxiliary dosimeter charger. The dosimeter may be worn in a pocket, on a belt, or clipped to a collar. Protective end caps are provided, which should be kept in place to minimize shock transmitted to the instrument. Mechanical abuse can cause the reading to shift, usually in an upscale or fail-safe direction.



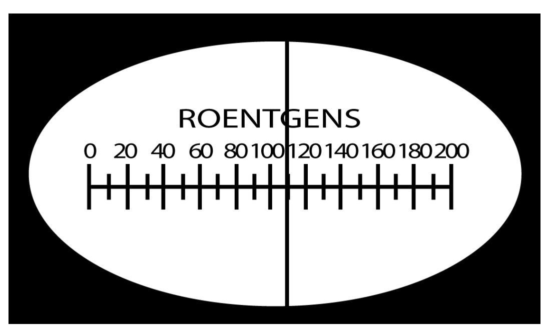
Reading #1

Reading the dosimeter

The dosimeter can be read at any time by holding it up to the light and looking through it. It is not necessary to remove either one of the end caps. The exposure in Roentgens received since the last time the unit was charged is read directly on the scale. Increase the accuracy of the reading by holding the dosimeter horizontally with the scale in a natural viewing position. Practice reading the following scales:



Reading #2



Reading #3

1.) ___________________________________

2.) ___________________________________

3.) ___________________________________

Electronic dosimeters

Example of an electronic dosimeter from RAE systems.

Purpose: These dosimeters, also known as PADI, usually measure only Gamma or X-ray radiation. They are worn by the worker. Some of these dosimeters have a digital display. Others are “chirpers.” They emit a series of audible “chirps.” The more frequent the chirps, the higher the exposure rate. Some dosimeters have an alarm that indicates the exposure is greater than a predetermined level. One type is called a pocket alarm dose indicator (PADI).

Principle of operation: The exact principle of operation depends on the make and model.

Proper use: Follow the instructions that come with the dosimeter. Follow the requirements on the radiological work permit (RWP). If you are not certain about how to use the dosimeter, ask your supervisor.

Objective 2: State the purpose and worker responsibilities for each type of internal monitoring method used at the site

Whole body counters, chest counters, and/or bioassay samples may be used to monitor radioactive material in the human body. In some cases, the locations of radioactive material may be determined. An internal dose estimate may be performed based on these measurements.

Purpose of each type of internal monitoring

Whole body counter


Whole body counter by Atomtex.

The whole body counter measures radiation emitted by radioactive materials within the body. You may be expected to receive a whole body count at the beginning and at the end of your employment, at regular intervals during employment, or after a suspected over exposure. The whole body counter is a laboratory instrument, set up in a special room that is heavily shielded from all outside sources of radiation. Do not confuse the “whole body counter” with a “whole body frisk” or a “personal contamination monitor.”

Bioassay

A bioassay is a laboratory analysis of urine or feces to determine if radioactive materials are present in these body materials. By measuring both the quantity of radioactive material eliminated, and its rate of elimination, it is possible to calculate internal radiation doses for certain isotopes. Bioassays can be used to measure all types of radioactive materials in bodily wastes, not just the Gamma emitters that whole body counters measure. You may be required to provide bioassay samples on a regular schedule, or following certain job assignments where an accidental internal contamination is a possibility.

Worker responsibilities

Each radiological worker is responsible for providing bioassay samples for analysis as required or when requested. The worker is also required to appear for a whole body count when requested.

Objective 3: State the methods for obtaining radiation dose records

Methods for obtaining radiation dose records

Individuals who are monitored for exposure at DOE facilities have the right to request reports of that exposure as follows:

Upon the request from an individual terminating employment, records of radiation dose shall be provided by the DOE facility/site within 90 days. If requested in writing, a written estimate of radiation exposure received by the terminating employee shall be provided at the time of termination.

Each individual required to be monitored for radiation exposure at a DOE facility/site shall receive a report of that exposure on an annual basis.

Detailed information concerning any individual's dose shall be made available to the individual upon request of that individual.

When a DOE contractor is required to report to the Department, pursuant to Departmental requirements for occurrence reporting and processing, any exposure of an individual to radiation and/or radioactive material, or planned special exposure, the contractor shall also provide that individual with a report on his/her exposure data included therein. Such a report shall be transmitted at a time not later than the transmittal to the Department.

Use the space below to enter any facility/site-specific procedures for obtaining your radiation dose records.

Objective 4: Identify worker responsibilities for reporting radiation dose received from other sites and from medical applications

Reporting radiation dose received from other facilities and from medical applications

Notify Radiological Control personnel prior to and following any radiation dose received at another facility/site so that dose records can be updated.

Notify Radiological Control of medical radioactive applications. This does not include routine medical and dental X-rays. This does include therapeutic and diagnostic radio-pharmaceuticals.

Use the space below to record facility/site-specific requirements for reporting radiation dose received from other sites and from medical applications.

IOUE equipment operators practice charging their dosimeters in a class exercise.

Activity 6.2: charging pencil dosimeter

Charging the dosimeter

The charging process is used to reset the dosimeter back to the zero reading. Zeroing the dosimeter is accomplished with a dosimeter charger using the following steps:

1. Remove the protective cap from the charging end of the dosimeter (opposite the alligator clip).
2. Place the dosimeter on the charging pedestal and press down.
3. While the dosimeter is pressed down, look through the eyepiece and adjust the “Upscale/Down scale” control knob until the fiber rests slightly below zero.
4. Remove the dosimeter, slowly allowing it to rest under its own weight on the pedestal for a moment.
5. Look through the eyepiece toward a light. If the fiber has drifted upscale or is off the zero position, repeat the procedure.
6. Replace the protective end cap. If the fiber has been off zero for more than one day, it may be necessary to re-zero the dosimeter after a few hours.

Using the procedures described above, read and zero your assigned dosimeters.

Dosimeter Number	*Initial Reading*	*Final Reading*
1.		
2.		
3.		

Review questions

1. The purpose of external dosimetry is to:

a. Measure dose from all ionizing radiation sources

b. Measure dose from natural sources of ionizing radiation

c. Measure dose from occupational radiation

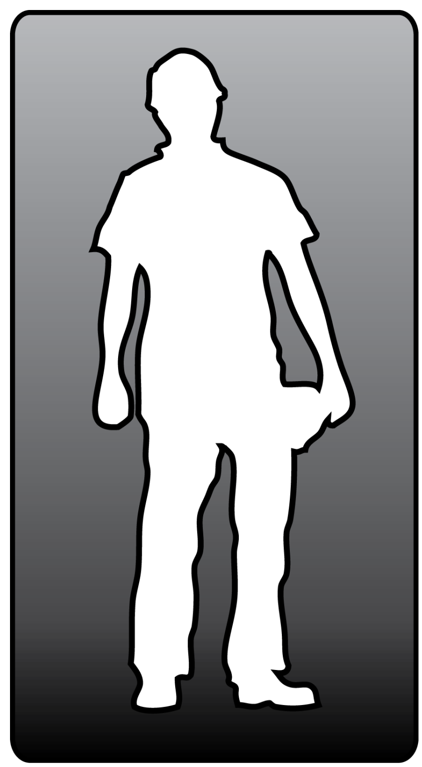
d. Measure dose from medical sources

2. External dosimetry measures which of the following:

a. Radiation emitted from the drum and radiation from the leak

b. Contamination leaking from the drum and contamination found inside the drum

3. Draw a dosimeter in the proper location on the person at the right



4. Internal monitoring provides detection of the following (check all that apply):

___ a. Natural sources - food, soil, etc.

___ b. Manmade sources - medical

___ c. Occupational sources

___ d. Non-ionizing sources

5. Examples of internal monitoring are (check all that apply)

___ a. Whole body counter

___ b. External dosimetry

___ c. Bioassay

___ d. Personal contamination monitor (PCM)

6. Dose reports are provided on an annual basis.

True_____ False____

7. Workers may get their current dose record via:

___ a. Their supervisor

___ b. The medical department

___ c. Written request

___ d. The security department

8. For dose received at another site the radiological worker must notify their Radiological Control Organization before and after the dose is received.

True_____ False____

9. You must notify the Radiological Control Organization for the following (check all that apply)

___ a. Dental X-rays

___ b. Radiation exposure received at another site

___ c. Sunburn

___ d. Chest X-ray.

___ e. Injection of radioactive isotopes for medical purposes

___ f. Lost dosimeter

10. Match the following items with the appropriate definition shown on the right.

_______ PADI

_______ TLD

_______ Finger ring

_______ Whole body counter

_______ Bioassay

a) This dosimeter measures the radiation dose to the hands

b) This supplemental dosimeter is used to measure exposure to Gamma radiation.

c) Very sensitive instrument used to detect small amounts of radioactive material inside the body.

d) A method for measuring an internal radiation dose by sampling body fluids for radioactive material.

e) This dosimeter measures the doses from penetrating Beta, Gamma, and neutron radiation.

11. List a worker's two main responsibilities concerning internal monitoring programs.

1. ____

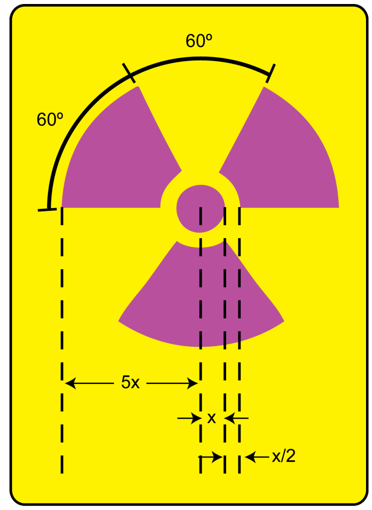
____

2. ____

____

Notes:

Module 7: Radiological Access Controls and Postings



Basic trefoil symbol with proportions based on a central circle of radius X. The minimum allowable size of X shall be 4mm.

Objectives

At the end of this module, you will have an understanding of the following:

- State the purpose of and information found on Radiological Work Permits (RWPs)
- Identify the worker's responsibilities in using Radiological Work Permits
- Identify the colors and symbols used on radiological postings
- State the radiological and disciplinary consequences of disregarding radiological postings, signs, and labels
- Define the areas controlled for radiological purposes
- Identify the minimum or recommended requirements for entering, working in, and exiting:
    - Radiological Buffer Areas
    - Radiation Areas
    - High radiation and very high radiation areas
    - Contamination areas and high contamination areas
    - Airborne radioactivity areas
    - Radioactive Material Areas
    - Underground Radioactive Material Areas
    - Soil Contamination Areas
    - Fixed Contamination Areas
- Identify the areas that a Radiological Worker I-trained person may enter
- Identify the purpose and use of personnel contamination monitors

Purpose of the module

In this module, radiological Work Permits (RWP) used to control access into areas controlled for radiological purposes will be addressed. In addition, radiological requirements for working in these areas will be presented. These concepts are important for worker protection—they will allow you to know what areas you can and cannot enter. This module will also cover topics such as what training is required and what procedures must be followed.

The previous modules discussed some important radiological topics from a theoretical perspective. The current module will discuss the application of these theories to control radiological work in a safe but efficient manner.

Objective 1: State the purpose of and information found on Radiological Work Permits (RWPs)

Purpose of RWPs

RWPs may be used to establish radiological controls for entry into areas controlled for radiological purposes. They serve to inform workers of area radiological conditions, entry requirements and, provide a record that relates radiation doses to specific work activities.

Types of RWPs

There are two types of RWPs. Which type is used depends on the radiological conditions in the area.

General Radiological Work Permit

This permit should be used to control routine or repetitive activities such as tours and inspections or minor work activities in areas with well characterized, stable radiological conditions. General RWPs should not be approved for periods longer than 1 year.

Give examples of when a General RWP should be used in the space provided below.

Job-specific Radiological Work Permit

This permit should be used to control non-routine operations or work in areas with changing radiological conditions. It should only remain in effect for the duration of a particular job.

Give examples of when a job-specific WRP should be used in the space provided below.

An alternate formal mechanism, such as written procedures, experiment authorizations, or other written authorization, may be used in lieu of an RWP. The alternate method should include the elements of an RWP.

Information found on the RWP

There is no required form for the RWP. This means that RWPs from different facilities may look different. However, the DOE requires that certain information be included in an RWP. The RWP shall include the following information:

- Description of work
- Work area radiological conditions. This information may also be determined from area radiological survey maps/diagrams or the radiological posting for that area
- Dosimetry requirements
- Pre-job briefing requirements. Pre-job briefings generally consist of discussions among workers and supervisor(s) concerning various radiological aspects of the job. The purpose of the briefings should be to discuss radiological exposure and appropriate actions for unplanned situations.
- Required level of training for entry
- Protective clothing/equipment requirements
- Radiological Control coverage requirements and stay time controls, as applicable
- Limiting radiological condition that may void the permit
- Special dose or contamination reduction requirements
- Special personnel frisking requirements
- Technical work document to be used, as applicable
- Date of issue and expiration
- Authorizing signatures and unique identifying designation or number

The following is an example of a RWP:

RADIATION WORK PERMIT

No. ____________

A Initiator (Faculty/Staff) ____________ Date ____________

B Expiration Time [ ] **Expiration Date** Mo. Day Year [ ] [ ] [ ]

C Work Location ____________

D Work Description (attach additional sheets as necessary)

Manual sample loading and unloading of rotary specimen rack (RSR) or CT center tube assembly. Temporary storage of samples in transfer cart (<24 hours) will be in a location that does not interfere with gamma ray counting. Long term storage of samples will be at the discretion of the HP. The pass through port will be used for transfer of radioative materials into Room 3.102. Use of the sample loading and unloading in the glove box also falls under this RWP.

Personnel working under this RWP must also read the attached supplement located behind the RWP.

E Personnel Authorized to work Under this RWP (Name, Position)

____
____
____
____
____
____
____
____
____

K Approvals (Signature & Date Required)

Health Physicist: ____________ Date: ____________

Reactor Supervisor: ____________ Date: ____________

Extension: ____________ Date: ____________

L Close-Out Request

Work Completed on ____________ (Date) Close-Out Requested By ____________ (Signature)

M Close-Out Certification

Required surveys completed, RWP closed out.

____________ (Health Physicist) Date: ____________

N Remarks:

RADIATION WORK PERMIT

This Section To Be Completed By Health Physics Personnel

F Personnel Protective Clothing, Respiratory Equipment (check all that apply)

√ Lab Coat	o Shoe Covers
o Coveralls over Street Clothes	o Rubber Boots
√ Gloves, Latex, OR	o Head Covering ______
√ Gloves, Orange, w/liners	o Full Anti-Contamination Suit
o Safety Glasses	o Face Shield
o Respiratory Equipment	o Air Sample Required
o Other (specify) ______	o Fume Hood Required

G Dosimetry and Survey Instruments (check all that apply)

o Neutron, whole body (trunk)	o Low Range Dose Rate (<200 mrem/hr)
√ Pocket Ionization Chamber	o High Range Dose Rate (>200 mrem/hr)
√ Gamma/Beta, Chest Badge (if issued)	o Portable Frisker
√ Extremity Badge (if issued)	o Hand and Foot Monitor
o Neutron, other (specify) ______	o Other (specify) ______

Special Instructions (Attach Additional sheets as necessary)
HP should be notified prior to sample handling and when complete. See attachment for specific procedures. RWP clearance may be by local swipe/counting by trained individuals.

H Health Physics Coverage (circle all that apply)

Initial **Intermittent** Continuous On Call Self Prior to Close-Out

I General Area Radiation Level	(mrem/hr)	<5	General Contamination Level	(DPM/100cm^2)	<200
Hot Spot Radiation Level	(mrem/hr)	500	Maximum Contamination Level	(DPM/100cm^2)	1000

J Person-mrem Limit: 100 Experiment Authorization No.

RWP BRIEFING LOG

To Be Completed By All Persons Working Under This RWP

I attest that I have read, understand, and shall comply with the requirements imposed by this RWP. NOTE: Failure to follow the provisions of this RWP will resultin withdrawal of RWP work privileges until further training is accomplished.

Signature & Date	Signature & Date
Signature & Date	Signature & Date
Signature & Date	Signature & Date
Signature & Date	Signature & Date
Signature & Date	Signature & Date
Signature & Date	Signature & Date

RADIATION WORK PERMIT

No.________

RWP ENTRY LOGSHEET

NAME (Printed)	DATE	TIME		INITIAL PD READING	FINAL PD READING	DOSE (FINAL-INITIAL)	PERSON mREM RUNNING TOTAL
		IN	OUT				
					PAGE TOTAL ->		

Objective 2: Identify the worker’s responsibilities in using Radiological Work Permits

Workers must read and comply with the RWP requirements. Workers must acknowledge they have read, understood, and agreed to comply with the RWP prior to entering the area and after any revision is made to the RWP. This is done by signature or through electronic means. Radiological Control or a supervisor should be contacted prior to work if the RWP appears to be incorrect or is difficult to understand. Do not make substitutions for specified requirements. The use of protective clothing or equipment beyond that specified by the Radiological Control Organization is not authorized. Report to Radiological Control personnel if radiological controls are not adequate or are not being followed.

Objective 3: Review radiological postings

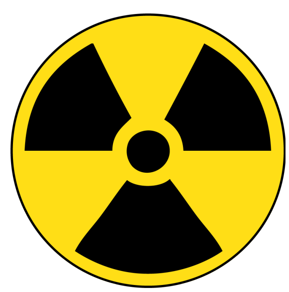
Radiological postings are used to:

- Alert personnel to the presence of radiation and radioactive materials
- Aid in minimizing personnel dose
- Prevent the spread of contamination

In addition, 10 CFR 835, Subpart F, specifies requirements for personnel entry controls for HR and VHR Areas.

Posting requirements

Areas and materials controlled for radiological purposes will be designated with a magenta or black standard three-bladed radiological warning symbol (trefoil) on a yellow background, as shown in the image to the right.



Note: The IAEA and ISO have announced an updated version of the above mentioned trefoil, ionizing radiation warning symbol. It was stated that, “the original symbol did not have an intuitive meaning and little recognition beyond those educated in its significance.” They have therefore designed the following supplemental symbol to represent ionizing radiation:

Fixed barriers such as walls, rope, tape, or chain will designate the boundaries of posted areas. Where possible, the barriers will be yellow or magenta in color. The barriers should be placed to clearly mark the boundary of the areas.

Entrance points to radiologically-controlled areas should have signs or postings stating the entry requirements, such as “Personnel Dosimeters, RWP and Respirator Required.”

In some cases, more than one radiological condition may be present. If this is the case, the area shall be posted to include all of the radiological conditions that are present.

In areas of ongoing work activities, the dose rate and contamination levels (or ranges of each) may be included in postings.

The posting will be placed where it is clearly visible to personnel.

Objective 4: Worker responsibilities for postings, signs and labels

Before entering an area controlled for radiological purposes, read all of the signs. Since radiological conditions can change, the signs will also be changed to reflect the new conditions. A sign or posting that you saw one day may be replaced with a new one the next day.

Obey any posted, written or oral requirements including “Exit,” “Evacuate,” “Hold Point,” or “Stop Work” orders These requirements may be included in

RWPs and work procedures, and may come from Radiological Control personnel at the job site.

Hold points are specific times noted in a procedure, work permit, etc., where work must stop for Radiological Control or other evaluations. Stop Work orders are usually the result of:

- Inadequate radiological controls
- Failure to implement radiological controls
- Radiological hold point not being observed
- Changing or unexpected conditions

Report unusual conditions such as leaks, spills, or alarming area monitors to the Radiological Control personnel. Be aware of changing radiological conditions. Be aware that others' activities may change the radiological conditions in your area. If any type of material used to identify a radiological hazard is found outside an area controlled for radiological purposes, it should be reported to Radiological Control personnel immediately.

Objective 5: State the radiological and disciplinary consequences of disregarding radiological postings, signs, and labels

Consequences of disregarding radiological postings, signs, and labels

It is each worker's responsibility to read and comply with all the information identified on radiological postings, signs, and labels.

Disregarding any of these or removing/relocating them without permission can lead to:

- Unnecessary or excessive radiation dose
- Personnel contamination
- Disciplinary actions such as formal reprimand, suspension, or even termination

Objective 6: Define the areas controlled for radiological purposes and entry requirements

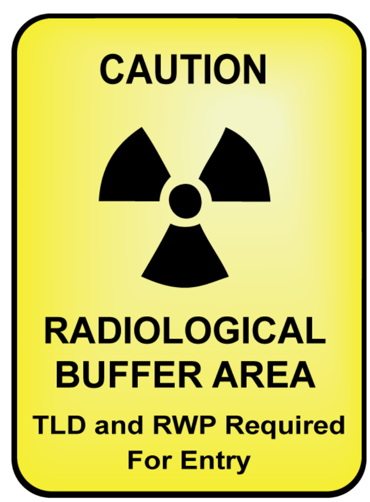
The level of training a radiological worker has successfully completed determines the types of areas he/she can enter. The following are the various areas controlled for radiological purposes and who may enter them:

- Radiation Areas
    - Radiation Area
    - High Radiation Area
    - Very High Radiation Area
- Contamination Areas
    - Contamination Area
    - High Contamination Area
    - Fixed Contamination Area
    - Airborne Radioactivity Area
    - Soil Contamination Area
- Radiological Buffer Areas
- Other Radiological Areas
    - Radioactive Materials Area
    - Underground Radioactive Materials Area

These areas are defined in depth in the text below.

Radiological Buffer Areas (RBAs)

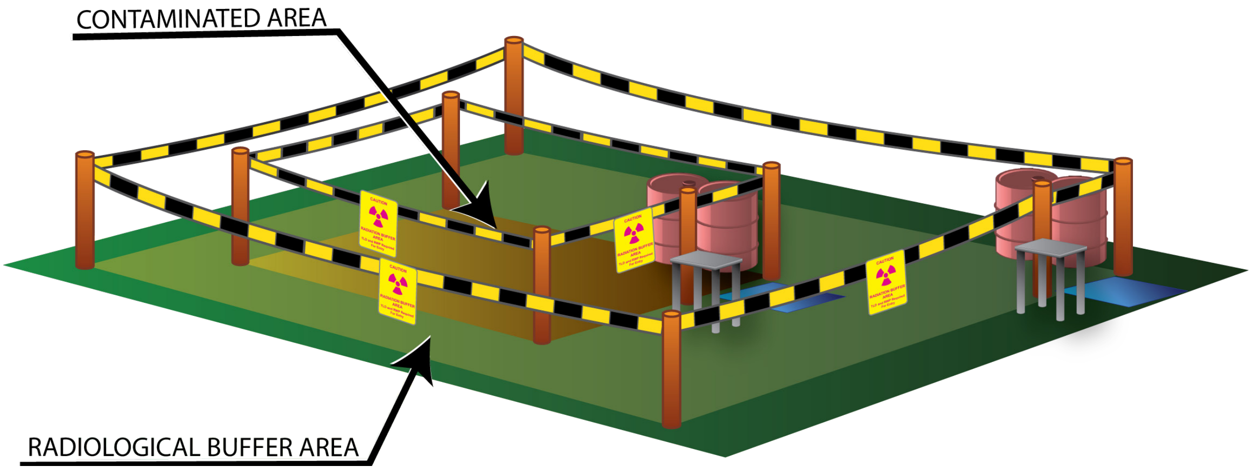
RBAs are intermediate areas that DOE RCS recommends be established to prevent the spread of radioactive contamination and to protect personnel from radiation exposure. This area designation is not required by 10 CFR 835 and its use may vary from site to site.



Posting Recommendations:

"CAUTION, RADIOLOGICAL BUFFER AREA"

The following diagram is an example of a barricaded, posted radiological area, including buffer area sign:



Recommended requirements for unescorted entry should include:

- Appropriate training, such as RWI training
- Personnel dosimetry, as appropriate
- Facility/site-specific RBA entry requirements

Requirements for working in the RBA

- Always practice ALARA
- Obey eating, drinking, smoking, or chewing policy
- Obey any posted, written, or oral requirements including “Evacuate,” “Hold Point,” or “Stop Work” orders from Radiological Control personnel

Facility/site-specific recommended requirements for working in RBA should be entered in the space provided below.

Recommended requirements for exiting an RBA:

Personnel exiting a RBA containing a Contamination Area, High Contamination Area, or Airborne Radioactivity Area should, at a minimum, perform a hand and foot frisk.

General guidelines for handheld monitoring using a hand-held radioactive contamination survey instrument include the following:

Geiger counter.

1. Verify the instrument is on, set to the proper scale, and enter the calibration date
2. Verify instrument response and source check
3. Ensure the audible function of the instrument is on and can be heard
4. Determine the instrument background

List facility/site-specific information concerning acceptable background rates in the space provided below.

5. Survey hands before picking up the probe.
6. Hold the probe approximately ½" from the surface being surveyed for Beta/Gamma and ¼" for Alpha radiation.
7. Move probe slowly over the surface, approximately 2" per second.
8. If the count rate increases during frisking, pause for 5 to 10 seconds over the area to provide adequate time for instrument response. When scanning for contamination there is a delay in instrument response. The cause of the increased count rate might be back a short distance from where the increased count rate was observed.

Alarm response for hand-held survey instrument

If contamination is indicated, remain in the area and notify the Radiological Control personnel. Try to minimize cross contamination. For example, put a glove on a contaminated hand while waiting for the Radiological Control personnel to arrive.

Portal monitors

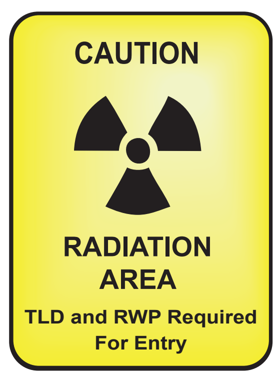
Insert facility/site-specific information.

Radiation Areas (RAs)

RAs are any areas accessible to individuals in which radiation levels could result in an individual receiving an equivalent dose to the whole body in excess of 5 mrem in one hour. This is established based on dose rates at 30 cm from the source of radiation or any surface that the radiation penetrates.

Posting Requirements:

"CAUTION, RADIATION AREA"



Additionally, the posting may state:

"Personnel Dosimetry Required for Entry"

Minimum requirements for unescorted entry should be:

- Appropriate training, such as Radiological Worker I Training
- Personnel dosimeter
- Worker's signature on the RWP, as applicable

Insert facility/site-specific information on unescorted entry into RAs in the space below.

Minimum requirements for working in an RA

- Don't loiter in the area
- Follow proper emergency response to abnormal situations
- Avoid hot spots

Hot Spots

Hot spots are localized sources of radiation or radioactive material normally within facility/site piping or equipment. The radiation levels of hot spots exceed the general area radiation level by more than a factor of 5 and are greater than 100 mrem per hour on contact.

Posting:

"Caution, Hot Spot"

Insert facility/site-specific information for working in RAs in the space provided below.

Minimum requirements for exiting a RA:

- Observe posted exit requirements
- Sign-out on RWP or equivalent, as applicable

Insert facility/site-specific information for exiting RAs in the space provided below.

Radioactive Materials Area (RMA)

RMA means an area, accessible to individuals, in which items or containers of radioactive material exist and the total activity of radioactive material exceeds ten times the applicable value provided in 10 CFR 835 Appendix E.

Radioactive material may consist of equipment, components, or materials that have been exposed to contamination or have been activated. Sealed or unsealed radioactive sources are also included. Radioactive material may be stored in drums, boxes, etc., and will be marked appropriately.

Posting Requirements:

"CAUTION, RADIOACTIVE MATERIAL(S)"

Exceptions to posting requirements for RMAs

Areas may be exempt from the posting requirements for periods of less than 8 continuous hours when placed under continuous observation and control by an individual knowledgeable of, and empowered to implement, required access and exposure control measures.

The following areas may be exempt from the radioactive material area posting requirements:

- Areas posted Radiation Area, High Radiation Area, Very High Radiation Area, Airborne Radioactivity Area, Contamination Area, or High Contamination Area
- Areas in which each item or container of radioactive material is clearly and adequately labeled in accordance with 10 CFR 835, such that individuals entering the area are made aware of the hazard
- The radioactive material consists solely of structures or installed components that have been activated
- Areas containing only packages received from radioactive material transportation labeled and in a non-degraded condition need not be posted in accordance with 10 CFR 835 until the packages are surveyed

Minimum requirements for unescorted entry should include:

- Appropriate training, such as RW I Training
- For entry into Radioactive Material Areas where whole body dose rates exceed 5 mrem in one hour, the Radiation Area entry requirements will apply
- For entry into Radioactive Material Areas where removable contamination levels exceed the specified DOE limits, the Contamination Area entry requirements will apply
- Insert facility/site-specific information on minimum requirements into RMAs in the space provided below

List facility/site-specific minimum requirements for working in an RMA in the space provided below.

List facility/site-specific minimum requirements for exiting an RMA in the space provided below.

Fixed contamination area (Recommended)

This area designation is recommended by the DOE RCS. It may be an area or equipment that contains radioactive material that cannot be easily removed from surfaces by nondestructive means, such as wiping, brushing, or laundering. This type of area designation is not required by 10 CFR 835 and its use may vary from site to site.

Recommended Posting:

“CAUTION, FIXED CONTAMINATION”

Contact the Radiological Control Organization for entry and exit requirements.

Record facility/site-specific information on entry and exit requirements into fixed contamination sites in the space provided below.

Soil contamination areas for work that doesn't disturb the soil (Recommended)

This area designation is recommended by the DOE RCS. It contains surface soil or subsurface contamination levels that exceed the recommended DOE limits. This type of area designation is not required by 10 CFR 835 and its use may vary from site to site.

Posting:

"CAUTION, SOIL CONTAMINATION AREA"

Contact the Radiological Control Organization for entry and exit requirements.

Record facility/site-specific information on entry and exit requirements into soil contamination sites in the space provided below.

Underground Radioactive Materials Areas (URMAS)

Where an Individual is not likely to receive a dose > 0.1 rem in a year (Recommended)

URMAS are area designations recommended by the DOE RCS. They are established to indicate the presence of underground items that contain radioactive materials such as pipelines, radioactive cribs, covered ponds, inactive burial grounds, and covered spills. This type of area designation is not required by 10 CFR 835, and its use may vary from site to site.

Posting:

"UNDERGROUND RADIOACTIVE MATERIALS"

Special instructions such as, "Consult with Radiological Control Organization before Digging" or "Subsurface Contamination Exists" may be included.

General requirements:

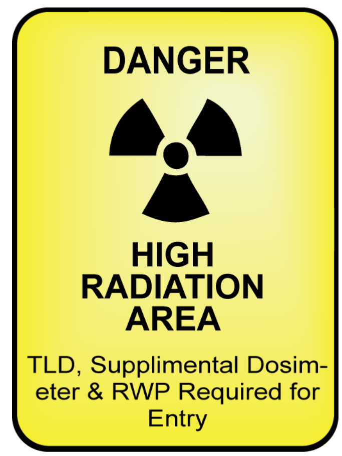
- An Underground Radioactive Materials Area may be exempt from the general entry and exit requirements if individual doses do not exceed 100 mrem in a year
- Contact the Radiological Control Organization prior to entry

Insert facility/site-specific information on URMASs in the space provided below.

Objective 6: Areas a RWI-trained person may not enter without additional training

High Radiation Areas (HRAs)

High radiation area means any area, accessible to individuals, in which radiation levels could result in an individual receiving an equivalent dose to the whole body in excess of 0.1 rems (0.001 Sv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates. Unescorted entry into this area requires appropriate training, such as RW II or RW I with the High Radiation Area training module.



Posting Requirements:

"CAUTION or DANGER, HIGH RADIATION AREA"

Additionally, the posting may state:

"Personnel Dosimetry Required for Entry"

Very High Radiation Areas (VHRs)

A VHR is any area accessible to individuals in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rad in one hour (rad is used instead of rem for limits associated with very high doses and dose rates) at 1 meter from the source or from any surface the radiation penetrates.

Posting Requirements:

"GRAVE DANGER, VERY HIGH RADIATION AREA"

Contamination Areas (CAs)

CAs are any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed the removable surface contamination values specified in Appendix D of 10 CFR 835, but do not exceed 100 times those values.

Posting Requirements:

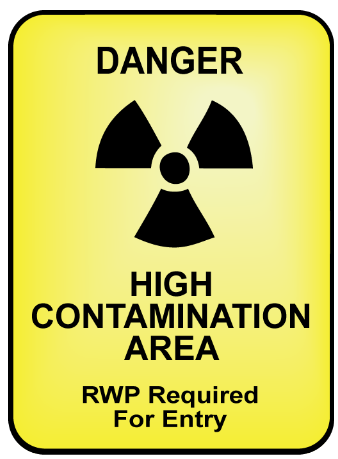
"CAUTION, CONTAMINATION AREA"

Unescorted entry into this area requires appropriate training, such as RW II training.

High Contamination Areas (HCAs)

An HCA is an area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed 100 times the removable surface contamination values specified in Appendix D of 10 CFR 835. Unescorted entry into this area requires appropriate training, such as RW II training.

Posting Requirements:



"CAUTION or DANGER, HIGH CONTAMINATION AREA"

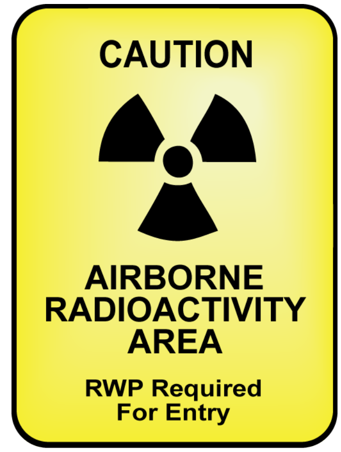
Additionally, the posting may state:

"RWP REQUIRED FOR ENTRY"

Airborne Radioactivity Areas (ARAs)

ARAs are those areas, accessible to individuals, where the concentration of airborne radioactivity, above natural background levels, exceeds or is likely to exceed the specified limits in 10 CFR 835. Unescorted entry into this area requires appropriate training, such as RW II training.

Posting Requirements:



"CAUTION or DANGER AIRBORNE RADIOACTIVITY AREA"

Additionally, the posting may state:

"RWP REQUIRED FOR ENTRY"

Summary

Enter any additional facility/site-specific information concerning radiation postings and controls in the space provided below.

Review questions

1. State the purpose of a radiological work permit (RWP).

____

____

____

____

____

2. Check the information found on an RWP. (Check all those that apply.)

___ Expiration date
___ Description of chemical hazards
___ Hot work permit requirements
___ Limiting radiological conditions that may void the permit
___ Material safety data sheets
___ Description of work
___Work area radiological conditions
___ Dosimetry requirements
___ Protective clothing
___ Lock out/tag out permit number
___ Authorizing signatures
___ Fire systems check out
___Worker's current dose

3. Identify the worker's responsibilities in using Radiological Work Permits. Identify which of the following are worker responsibilities concerning RWPs. (Check all those that apply.)

___Workers must read the RWP
___Workers must write the RWP
___Workers must comply with the RWP requirements
___Workers may substitute controls specified in the RWP
___Workers may continue to work in an area covered by an RWP even if instruc tions are not clear
___Workers must contact the Radiological Control personnel if RWP controls are not being followed

4. Describe the colors and symbols used on radiological postings.

____

____

5. State the radiological and disciplinary consequences of disregarding radiological postings, signs and labels.

____

____

____

6. Identify the minimum requirements for entering, working and exiting a radiological buffer area.

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7. Identify the minimum requirements for entering, working and exiting a radiation area.

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8. State the personnel frisking requirements when exiting a radiological buffer area.

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Notes:

Module 8: High Radiation Areas and Very High Radiation Areas

Objectives

At the end of this module, you will have an understanding of the following:

- Define “High Radiation Area” and “Very High Radiation Area”
- Identify sources and locations that may produce High Radiation Areas and Very High Radiation Areas at the site
- State the minimum requirements for entering, working in, and exiting High Radiation Areas
- State the administrative and physical controls for access to High Radiation Areas

Purpose of the module

This module discusses information regarding entry, working in, and control of High Radiation Areas and the materials and systems that can emit high radiation levels. The High Radiation Area module familiarizes the participant with requirements for entry, work in, and exit from High Radiation Areas. Radiological Worker Modules 1-7 (core academic material) are a prerequisite for this module. If prerequisite requirements are met, this module may be taught alone.

Workers clean up radiological materials.

Objective 1: Define “High Radiation Area” and “Very High Radiation Area”

High Radiation Area

A High Radiation Area (HRA) is any area, accessible to individuals, in which radiation levels could result in an individual receiving an equivalent dose to the whole body in excess of 0.1 rem (100 mrem), but less than or equal to 500 rad in one hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

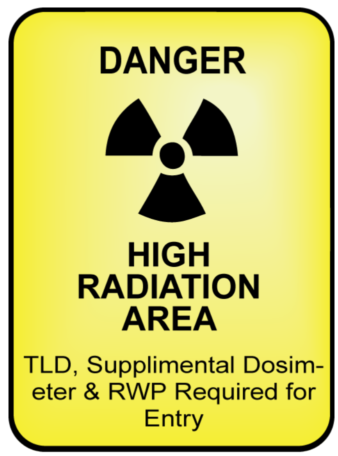
Signs and postings for HRAs

High Radiation Areas will be posted with a standard radiation symbol colored magenta (or black) on a yellow background, reading:

“CAUTION”
or
“DANGER HIGH RADIATION AREA”

Additionally the posting may state:

“Personnel Dosimeter, Supplemental Dosimeters, and RWP Required for Entry”



Very High Radiation Area

A Very High Radiation Area (VHRA) is any area, accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads in one hour at 1 meter from a radiation source or from any surface that the radiation penetrates.

Signs and postings for VHRAs

Very High Radiation Areas will be posted with a standard radiation symbol colored magenta (or black) on a yellow background, reading:

"GRAVE DANGER,
VERY HIGH RADIATION AREA"

Additionally the posting may state:

"Special Controls Required for Entry"

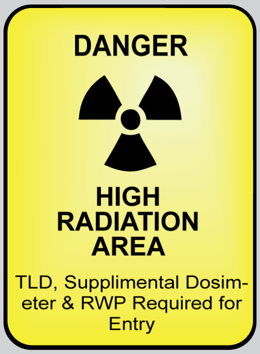
Some HRAs and VHRAs only exist when machinery is energized, such as radiation producing devices. For example, a posting could be:

"High Radiation Area When Warning Light is On"
"Controlled Area When Warning Light is Off"

Objective 2: Identify radiation sources at your site

It is important that you understand the type of sources that you will encounter at your site. As each site and job is different, be sure you find this information out during site/facility-specific training.

Insert facility/site-specific information on radiation sources that can produce High/Very High Radiation Areas and the location of each in Table 8.1 on page 8-4.

Table 8.1: High and Very High Radiation Area Definitions and sources (covering objectives 1 and 2)		
Sign	Definition	Facility/site-specific sources and locations
	> 100 mrem in 1 hour This is taken at 30 centimeters from the source of radiation or any surface that the radiation penetrates.	
	> 500 rad in 1 hour This is taken at 100 centimeters from the source of radiation, or any surface that the radiation penetrates.	

Objective 3: Requirements for entry, working in, and exiting high radiation areas

Entry, Work in, and exit from High Radiation Areas

Minimum requirements for entering HRAs

- Radiological Worker I Training plus High Radiation Area Training or Radiological Worker II Training
- Worker signature on the appropriate Radiological Work Permit (RWP)
- Personal and supplemental dosimeter

- Survey meter(s) or dose rate indicating device available at the work area (may be required for certain jobs)
- Access control
- A radiation survey prior to first entry
- Notification of operations personnel

Additional requirements where dose rates are greater than 1 rem in an hour. These should include:

- Determination of worker's current dose
- Pre-job briefing, as applicable
- Review and determination by the RCO regarding the level of RC technician coverage
- Access Points secured by control devices (required by 10 CFR 835)

Insert additional measures to ensure personnel are not able to gain unauthorized or inadvertent access to Very High Radiation Areas in the space provided below.

Minimum requirements for working in HRAs

- Don't loiter
- Practice ALARA

Insert facility/site-specific information for working in HRAs in the space provided below.

Minimum requirements for exiting HRAs

- No controls shall be established in a Radiological Area that would prevent rapid evacuation of personnel
- Sign out on RWP, as applicable

Insert facility/site-specific information for working in HRAs in the space provided below.

Objective 4: Access controls for high and very high radiation areas

There are different controls that are used to prevent the inadvertent entry or unauthorized access into Radiological Areas. The following identifies administrative and physical controls that are used for HRAs.

Administrative controls

The following are administrative controls that may be used to control access to HRAs. These are used in addition to physical controls.

- Formal radiological reviews
- RWPs
- Pre-job briefings
- Procedures
- Postings
- Administrative control levels (ACLs)

Insert facility/site-specific information for HRA administrative controls in the space provided below.

Physical controls

One or more of the following methods should be used for each entrance or access point to an HRA. These methods shall be used for HRAs >1 rem in any one hour at 30 cm from the radiation source or any surface the radiation penetrates. It should be noted again that no controls shall be established in an HRA or VHRA that would prevent rapid evacuation of personnel.

- A control device that prevents entry or upon entry causes the radiation level to be reduced below that level defining an HRA
- An automatic device that prevents use or operation of the radiation source
- A control device that energizes a visible or audible alarm
- Entryways that are locked. Maintain positive control over each entry.
- Continuous direct or electronic surveillance
- A control device that will automatically generate audible and visual alarm signals to alert personnel in the area before use or operation of the radiation source. The alarms must be issued in sufficient time to permit evacuation of the area or activation of a secondary control device that will prevent use or operation of the source.

Insert facility/site-specific information for HRA physical controls in the space provided below.

Violation of a radiological boundary, posting or bypassing a physical access control is a serious issue, likely to result in damage to equipment and/or injury to personnel.

Consequences of violating radiological signs or postings, or bypassing physical access controls include the following:

- Equipment damage
- Personnel injury
- Excessive and unplanned personnel exposure
- Disciplinary action

Access to VHRAs

Due to the extremely high dose rates in a VHRA, personnel access to these areas needs to be strictly monitored and controlled. Additional training would be required, as well as enhanced monitoring.

Summary

Now that you have completed module 7, "Radiation Postings and Controls" and module 8, "High and Very High Radiation Areas", you can see that there are many different types of defined areas and that each area has different requirements. It is important for you to understand the different postings, entry, work and exiting requirements for each as these areas. This knowledge, along with compliance with safety policies, will help keep you and your co-workers safe.

Review questions

1. Match the definition to the area listed on the right. You may wish to use the information in Module 7 for assistance.

a. ______ HRA

b. ______ CA

c. ______ RBA

d. ______ RA

e. ______ ARA

f. ______ VHRA

g. ______ RMA

(1) Any area accessible to individuals in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 5 mrem/hr but less than or equal to 100 mrem/hr. This is established based on dose rates at 30 cm from the source of radiation.

(2) Areas accessible to individuals in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rad/hr at 1 meter from the source of radiation.

(3) Areas where the concentration of airborne radioactivity, above natural background levels, exceeds or is likely to exceed the specified DOE limits.

(4) Areas accessible to individuals in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 100 mrem/hr at 30 centimeters from the source but less than or equal to an absorbed dose of 500 rad/hr at 1 meter from the source of radiation.

(5) Areas where contamination levels are greater than 1, but less than or equal to 100, times the specified DOE limits.

(6) Established within controlled areas to provide secondary boundaries to minimize the spread of radioactive contamination and to limit doses to general employees who have not been trained as Radiation Workers.

(7) An area where radioactive materials are used, handled or stored. This posting will not be required when radioactive materials are inside contamination or airborne radioactivity areas.

2. What are the minimum requirements for entry into a high radiation area?

____

____

____

3. Label each of the following by placing an administrative or physical control next to each of the controls.

Formal radiological reviews: ____

RWPs: ____

Locked entry ways: ____

Procedures: ____

Alarms: ____

Direct surveillance: ____

Notes:

Module 9: Contamination Control

Objectives

At the end of this module, you will have an understanding of the following:

- Define fixed, removable, and airborne contamination
- State sources of radioactive contamination
- State the appropriate response to a spill of radioactive material
- Identify methods used to control radioactive contamination
    - Identify the proper use of protective clothing
    - Identify the purpose and use of personnel contamination monitors
    - Identify the normal methods used for decontamination
- Define "Contamination," "High Contamination," and "Airborne Radioactivity Areas"
- Identify the minimum requirements for entering, working in, and exiting Contamination, High Contamination, and Airborne Radioactivity Areas

Purpose of the module

This unit is designed to inform the worker of sources of radioactive contamination. It will also present methods used to control the spread of contamination. Contamination control is one of the important aspects of radiological protection. Using proper contamination control practices helps to ensure a safe working environment. It is important for all employees to recognize potential sources of contamination and to use appropriate contamination control methods.

A radiological worker sprays an encapsulant on a contaminated surface. Hanford site. Courtesy DOE.

RAD WORKER II

Objective 1: Define fixed, removable, and airborne contamination

Comparison of Ionizing Radiation and Radioactive Contamination

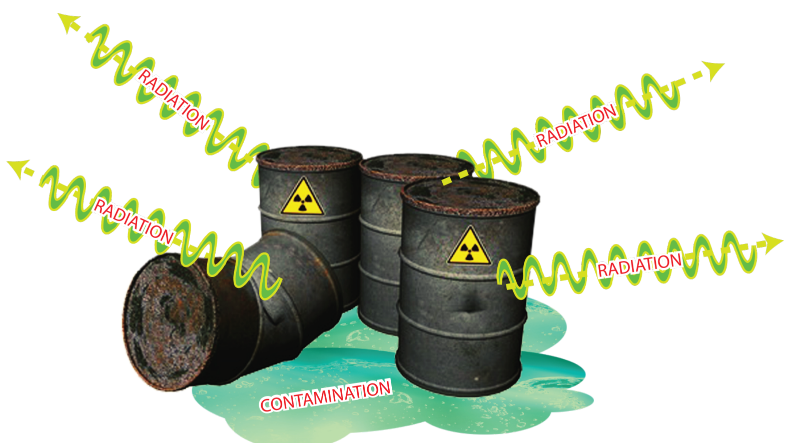
Ionizing radiation

The following is a working definition of ionizing radiation: energy (particles or rays) emitted from radioactive atoms or generated from machines, such as X-ray machines, that can cause ionization (e.g., Gamma rays, X-rays, Beta particles, and other particles capable of ionizing atoms).

Radioactive contamination

Radioactive material is material that contains radioactive atoms. When radioactive material is properly contained, it still emits radiation and may be an external dose hazard, but it is not a contamination hazard. When radioactive material escapes its container, it is then referred to as radioactive contamination, i.e., radioactive material in an undesired location.

Radiation is energy; contamination is a material. Remember, contamination may be radioactive and can give off radiation.



Radioactive contamination may give off radiation.

Fixed, removable and airborne contamination

Fixed contamination is contamination that cannot be easily removed from surfaces. It cannot be removed by casual contact. It may be released when the surface is disturbed (buffing, grinding, using volatile liquids for cleaning, cutting piping that is internally contaminated, etc.) Over time it may "weep," leach, or otherwise become loose or removable.

Removable contamination is contamination that can easily be removed from surfaces. Any object that comes in contact with it may become contaminated. The contamination may be transferred by casual contact, wiping, brushing, or washing.

Air movement across removable contamination could cause the contamination to become airborne. Airborne radioactivity is radioactive contamination suspended in the air.

Table 9.1 Types of Radioactive Contamination

Types	Definitions
Fixed Contamination	Cannot be removed by casual contact. It may be released when the surface is disturbed (buffing, grinding, using volatile liquids for cleaning, cutting piping that is internally contaminated, etc.) Over time, may become loose or removable.
Removable Contamination	May be transferred by casual contact. Any object that makes contact with it may in turn become contaminated. Air movement across removable contamination may cause the contamination to become airborne.
Airborne Radioactivity	Airborne radioactivity is radioactive contamination suspended in the air.

Objective 2: State some sources of radioactive contamination

Radioactive Contamination

Radiological work is required in areas and in systems that are contaminated by design (e.g., maintenance of valves in radioactive fluid systems). Regardless of the precautions taken, radioactive material will sometimes contaminate objects, areas, and people.

The following are some sources of radioactive contamination.

- Leaks or breaks in radioactive fluid systems
- Leaks or breaks in air-handling systems for radioactive areas
- Airborne radioactivity depositing on surfaces
- Leaks or tears in radioactive material containers, such as barrels, plastic bags or boxes
- Another common cause of contamination is sloppy work practices. These may lead to contamination of tools, equipment, and workers. Examples include:
    - Opening radioactive systems without proper controls
    - Poor housekeeping in contaminated areas
    - Excessive motion or movement in areas of high contamination
    - Improper usage of step-off pads and change areas
    - Violation of contamination control ropes and boundaries
- Hot particles: small, sometimes microscopic pieces of highly radioactive material may escape containment. These pieces are known as "hot particles." Hot particles may be present when contaminated systems leak or are opened. These particles may also be present when machining, cutting, or grinding is performed on highly radioactive materials. Hot particles can cause a high, localized radiation dose in a short period of time if they remain in contact with skin.

Indicators of possible contamination:

Radiological workers should be aware of potential radioactive contamination problems. Potential contamination problems should be reported to the Radiological Control Organization. Examples include:

- Leaks, spills, or standing water that is possibly from a radioactive fluid system
- Damaged or leaking radioactive material containers
- Open radioactive systems with no observable controls
- Dust/dirt accumulations in radioactive contamination areas
- Torn or damaged tents and glove bags or containments on radioactive systems

Workers begin demolition of the 183KW chemical storage silo by bringing the 40-foot-tall silo to ground level. The silo is part of the 183KW Sedimentation Basin complex that is being demolished using Recovery Act funds. Courtesy DOE.

Objective 3: State the appropriate response to a spill of radioactive material

Each of the examples listed above may become a spill of radioactive material. DOE has suggested a list of steps to take during a radiological emergency; depending on what type of emergency it is. Also, the site you are working on should have a standard set of emergency response procedures for a given situation. Each worksite (doe or non-doe) must have a plan for controlling a spill of radioactive material.

"Good Housekeeping" is a prime factor in an effective contamination control program. Each radiological worker should keep his/her work area neat and clean to control the spread of contamination.

Activity 9.1: Responding to a radiological emergency

Available time: 10 minutes to complete the activity and 5 minutes for report back.

Objective: This activity provides an opportunity to think about how having a good emergency response plan (even if it is to evacuate and call for outside help), can help reduce injuries and save lives. Be sure you can justify and explain your answers!

The Scenario:

Task: Your group is part of the team that was working on the pipe system. Look at the 10 actions listed below. Decide which action you should take first, second, third, and so on. Assemble the cards in an order you believe is correct and then write them down on a flip chart for group feedback, beginning with the first step. Be prepared to defend your selections.

Alert others on site	Treat the injured (first aid or place in ambulance)
Rescue the injured	Control the hazard
Evacuate the area	Notify government agencies
Evaluate the response	Decontaminate the injured
Retrieve response equipment	Size up the situation

The following list describes the minimum response to a spill of radioactive material:

- Stop or secure the operation causing the spill, if qualified
- Warn others in the area
- Isolate the area
- Minimize exposure to radiation and contamination
- Secure unfiltered ventilation, if qualified to do so
- Notify Radiological Control personnel

We will discuss emergency alarms and appropriate responses to emergencies throughout this module.

Objective 4: Identify methods used to control radioactive contamination

Contamination control methods

Every radiological worker should perform work in such a manner as to minimize the generation of radioactive contamination and to confine the spread of radioactive contamination to the smallest area possible. By controlling contamination, the worker minimizes the potential for internal exposure, and personnel contamination.

The following section describes methods used to control the spread of radioactive contamination.

Prevention

A sound maintenance program can prevent many radioactive material releases.

- Establish a solid routine maintenance program for operating systems. The maintenance program minimizes failures and leaks that lead to contamination
- Repair leaks as soon as identified to prevent a more serious problem

- Establish adequate work controls before starting jobs
- During pre-job briefings, discuss measures that will help reduce or prevent contamination spread. The agreed upon measures should be implemented by workers at the job site.
- Change protective gear (e.g., gloves) as necessary (typically as directed by Radiological Control personnel) to prevent cross-contamination
- Stage areas to prevent contamination spread from work activities
  - Cover work area to minimize cleanup afterward
  - Cover piping/equipment below a work area to prevent dripping contamination onto cleaner areas
  - Cap contaminated pipes or systems when not in use
- Prepare tools and equipment to prevent contamination
  - Bag or sleeve hoses and lines to prevent contamination
  - Minimize the equipment and tools taken into and out of contamination areas
  - Cover/tape tools or equipment used during the job to minimize decontamination after the job (e.g., taping up a screwdriver before use)
- Use good housekeeping practices; clean up during and after jobs
- Use standard contamination control procedures as established by the Radiological Control Organization
  - Do not violate contamination area ropes or barricades
  - Frisk materials out of contamination areas as directed by site procedures
  - Use change areas and step-off pads as directed
  - Do not pass items out of contamination areas without following site procedures
  - Be alert for potential violations of contamination control procedures
- Ensure ventilation systems are operating as designed (i.e., no unauthorized modifications)
- Radiological workers should always ensure that the proper entry, exit, and equipment control procedures are used to avoid the spread of contamination. Comply with procedures!!

Engineering controls

Ventilation

Systems and temporary spot ventilation (e.g., temporary enclosures with HEPA filters) are designed to maintain airflow from areas of least contamination to areas of most contamination (e.g., clean to contaminated to highly contaminated areas). A slight negative pressure is maintained on buildings/rooms/enclosures where potential contamination exists. High Efficiency Particulate Air (HEPA) filters are used to remove radioactive particles from the air.

Portable Ventilation Units. West Valley, NY site. Courtesy DOE.

Containment

Permanent and temporary containments are used for contamination control. Examples include vessels, pipes, cells, glove bags, glove boxes, tents, huts, and plastic coverings.

A worker performing "glove box" work at DOE site Hanford, WA.

Personal protective measures

Sometimes engineering controls cannot eliminate contamination. Personnel protective measures, such as protective clothing and respiratory equipment, will be used at this point.

Personal Protective Clothing (PPE)

Protective clothing is required when entering areas containing contamination and airborne radioactivity levels above specified limits to prevent personnel contamination. The amount and type of protective clothing required is de-

NOTE: Cotton glove liners may be worn inside rubber gloves for comfort, but should not be worn alone or considered as a layer of protection against contamination.

pendent on work area radiological conditions and the nature of the job. Your personal protective equipment (PPE) might be all that stands between you and having your skin or clothing becoming contaminated. Knowing how to select, put on, use, and take off your PPE will help to ensure that you are protected against this hazard. This section will teach you how to select, use and take care of your PPE and to understand its limits. Personal effects such as watches, rings, jewelry, etc., should not be worn. A full description of PPE will be discussed on pages 9-11 through 9-14. Full protective clothing generally consists of:

- Coveralls or splash suite (may be different type of cloth, tyvek or a combination of materials)
- Cotton liners
- Rubber gloves
- Shoe covers
- Rubber overshoes
- Hood

Proper use of protective clothing

Inspecting and being able to properly use PPE is a very important skill that provides you protection while working in radiological contamination areas. The following is a basic list of inspection and handling instructions for using PPE.

- Inspect protective clothing for rips, tears, or holes prior to use. If you find damaged protective clothing, discard properly
- Supplemental and multiple dosimeters should be worn as prescribed by the Radiological Control Organization
- After donning protective clothing, proceed directly from the dress-out area to the work area
- Avoid getting coveralls wet. Wet coveralls provide a means for contamination to reach the skin/clothing
- Contact Radiological Control personnel if clothing becomes ripped, wet, or otherwise compromised

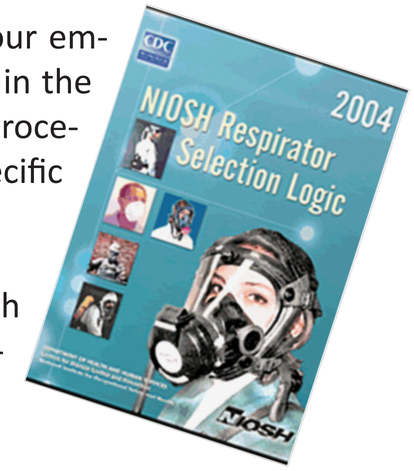

APR respirator with HEPA/Acid Gas/Organic Vapor compo cartridge.

Respiratory protection (respirators)

This training course DOES NOT qualify a worker to wear respiratory protection equipment! However, a brief review of respirators and what is expected from an employer who requires a worker to use respiratory protection is presented below to make you aware of what to expect.

Respirators are designed to ensure that you do not breathe harmful air while working in contaminated atmospheres. Using respirators in an effective manner is a complicated business. Not all respirators protect you from all airborne contaminants. There are many types to choose from and they must be carefully selected for each situation. Also, respirators do not always provide enough protection. To protect you, they must be used correctly and be carefully maintained. OSHA has published a specific standard for respirators, 29 CFR1910.134 Respiratory Protection. The Respiratory Protection standard requires employers to take all the necessary steps to ensure that respirators will effectively protect their employees. If you will be working where there is a possibility of airborne radioactive contamination, you will need to be placed in a respiratory protection program. OSHA requires that your employer have a written Respiratory Protection Program at any site where respirators are required for worker protection. The program is an employer's written plan of how the aspects of the standard will be met and should include written operating procedures for:

- Selecting appropriate respirators
- Medically evaluating potential respirator users
- Fit testing all tight-fitting respirators
- Training
- Adequate air quality, quantity and flow
- Using respirators in routine and emergency situations
- Maintaining respirators (cleaning, disinfecting, storing, inspecting and testing, repairing, discarding)
- Administered and maintained by a qualified person (IH, Safety Professional, etc.)
- Evaluating the program



If you are required to wear respirators on the job, your employer must have these written procedures compiled in the form of a program. He or she must train you on the procedures. Your employer must also train you on the specific respiratory hazards at your work place.

The National Institute of Occupational Safety and Health (NIOSH) is responsible for selecting respirator producers and certification of respiratory equipment.

Respirators for protection against radioactive contamination will either:

- Supplied air line or Self Contained Breathing Apparatus (SCBA)
- Powered Air Purifying Respirator (PAPR) with a hood, helmet or tight-fitting facepiece
- Air Purifying Respirator (APR) with High Efficiency Particulate Air (HEPA) filters

Putting it all together

Depending on what level of PPE you must wear to conduct your work, you may be wearing one of four different levels: Level A, Level B, Level C or Level D PPE. These different ensembles offer different levels of respiratory and skin protection. Although an in depth discussion of the four levels of PPE is beyond this class, they are outlined below.

Level A protection description

Level A consists of a gas/vapor tight suit with a supplied air respirator. It provides the maximum level of skin and respiratory protection against chemicals. It is designed to prevent contact of skin and body parts with hazardous vapors, liquids and solids. Conditions that warrant Level A protection include:

- High potential for splash or immersion, or potential exposure to gases or vapors

- that can harm or be absorbed through the skin
- Potential exposure to unknown vapors, gases, particulates
- Potential for direct skin and eye contact
- Potential for exposures above IDLH
- Effects of substance on skin are unknown

Level A protection is considered necessary when little is known about the nature or amount of the hazardous material. It is the highest level of PPE and respirator protection against hazardous chemicals. But, it is not without its own hazards. It is difficult to see, maneuver and communicate when wearing this level of protection. Heat stress is also a concern because the suits are air-tight. Therefore, it is recommended that only highly-trained workers use this level of protection in the most extreme of circumstances.

Level B protection description

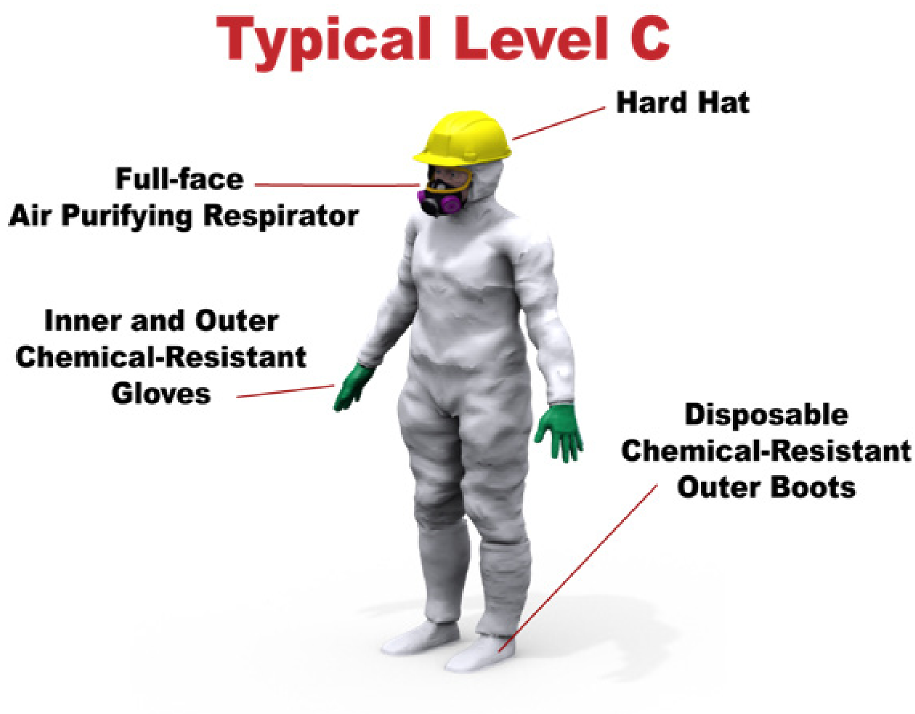
Protective clothing worn with maximum respiratory protection. Level B is designed to minimize or prevent contact of skin and body parts with hazardous substances. It will not prevent skin absorption of gases or vapors nor protect against extensive contact with hazardous materials.
Conditions that warrant Level B protection include:

- Limited direct skin and eye contact with hazardous chemicals or air contaminants that will not result in severe damage or irreversible effects
- Work function involving the potential for only minor splashes
- Potential exposure to IDLH or oxygen-deficient atmospheres

Level C protection description

This is the same protective clothing as Level B, but is worn with air purifying respirators. It is designed to minimize contact with many hazardous substances. Conditions that warrant Level C protection include:

- Limited direct skin and eye contact with hazardous compounds or air contaminants that will not result in severe damage or irreversible effects
- Work function involves potential for only minor splashes
- Conditions appropriate for air-purifying respirator



Level D protection description

Level D protection is a basic work uniform which may include PPE such as safety glasses, safety shoes, hearing protection and work gloves. It does not offer respiratory protection and offers limited skin protection (chemical protective aprons and gloves may be used to handle minor chemical processes, such as transferring chemicals that pose a low respiratory hazard but a slight skin hazard).

Table 9.2 below summarizes the four different levels of PPE.

Table 9.2 Levels of PPE	
Level A	Should be worn when the highest level of respiratory, eye and skin protection is needed.
Level B	Should be worn when the highest level of respiratory and eye protection is needed but a lesser level of skin protection is needed.
Level C	Should be worn when the criteria for air purifying respirators are met and some level of skin protection is needed.
Level D	Should be worn as basic work uniform where no respiratory or skin hazards are present. It provides no respiratory protection and minimal skin protection.

Activity 9.2: Dressing out some volunteers

Time for activity: 15 minutes

Objective: The goal of this activity is to show three to five different types of PPE ensembles and how they should be worn.

Task: Three to five volunteers will be needed to conduct this activity along with a partner for each volunteer (so a total of six to ten participants). The instructors will have three to five PPE ensembles laid out for you to put on in a group style demonstration.

Contamination monitoring equipment

Purpose

Contamination monitoring equipment is used to detect radioactive contamination on personnel and equipment. You may have heard of these by the names of Geiger Counter or Radiation Detector.

Two examples of hand-held radiation contamination monitoring meters.

Types and uses

Hand-held contamination monitor procedure:

- Verify instrument is in service, set to proper scale, and has functioning audio equipment
- Note background count rate at frisking station
- Frisk hands before picking up the probe
- Hold probe approximately ½ inch from surface being surveyed for Beta/Gamma and ¼ inch for Alpha radiation.

- Move probe slowly over surface, approximately 2 inches per second. Note, this is often the task that is conducted incorrectly. Move the meter SLOWLY!
- Perform frisk as follows:

1. Head (pause at mouth and nose for approximately 5 seconds)
2. Neck and shoulders
3. Arms (pause at each elbow)
4. Chest and abdomen
5. Back, hips, and seat of pants
6. Legs (pause at each knee)
7. Shoe tops
8. Shoe bottoms (pause at sole and heel)
9. Personal and supplemental dosimetry

- The whole body survey should take at least 2-3 minutes
- Carefully return the probe to holder. The probe should be placed on the side or face up to allow the next person to monitor
- If the count rate increases during frisking, pause for 5-10 seconds over the area to provide adequate time for instrument response. When scanning for contamination there is a delay in instrument response and the cause of the increased count rate might be back a short distance from where the increased count rate was observed.
- Take appropriate action if contamination is indicated:

1. Remain in the area
2. Notify Radiological Control personnel
3. Minimize cross-contamination (e.g., put a glove on a contaminated hand)

You may also encounter ½ body contamination detector machines which will cover two separate haves of the workers body to effectively give a whole body reading for contamination.

½ contamination detector (back) + (front) + Portable ½ body contamination detector (sides) + Portable ½ body contamination detector showing contamination (fiesta ware plate).

List site -specific notes on radiation survey meters in the box below.

Activity 9.3: Using a radiation contamination detector

Time for activity: 75 minutes (60 for group work and 15 for report back)

Objective: The goal of this activity is to allow participants to practice using a hand-held radiation contamination detector.

Task: In your groups, locate table(s) with hand-held radiation contamination detectors. Follow the step-by-step process for each table, and as demonstrated, conduct a review of the following radiation sources and record your findings. Your instructor will notify you when it is time to change stations.

Station 1: Use the radiation survey meter with pancake probe to obtain the following readings. Indicate readings in counts per minute (cpm).

Distance from source (inches)	Source 1	Source 2	Source 3
Name each source →			
1			
2			
3			
4			
6			
8			

Station 2: Set the survey meter on (Aud-on), and (S-Slow). Before you begin, record the names of your three sources in the spaces provided in the second row of the table. Also record a background reading to establish your environment's baseline radiation level. Focus on recording all of the shields for each individual source. Start by recording the unshielded source. Next, add a shield as indicated in the table and gently hold the detector against the shield. Place the various shields over the source one-by-one according to order listed in the following table. Indicate the activity of the three sources in counts per minute (cpm). (For best results, use shields that have the same thickness.)

Shield type	Source 1	Source 2	Source 3
Name each source →			
Background Reading			
Unshielded Source			
Paper			
Glove			
Plywood			
Sheet metal			
Lead			
Concrete			

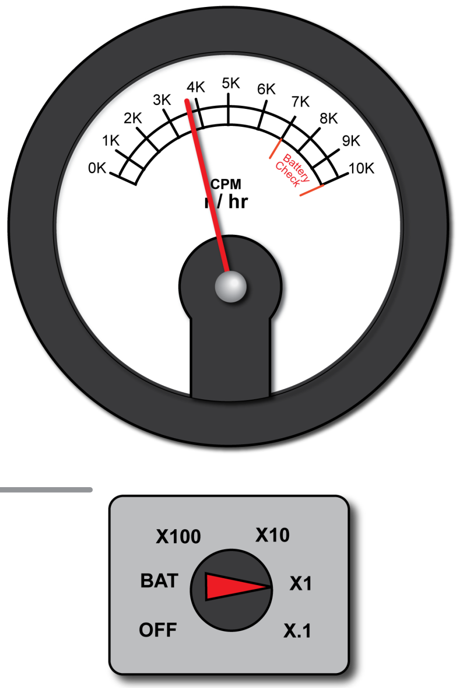
Station 3: Have a volunteer act as the worker exiting the contamination area and perform a frisking procedure with a radiation survey meter as outlined below.

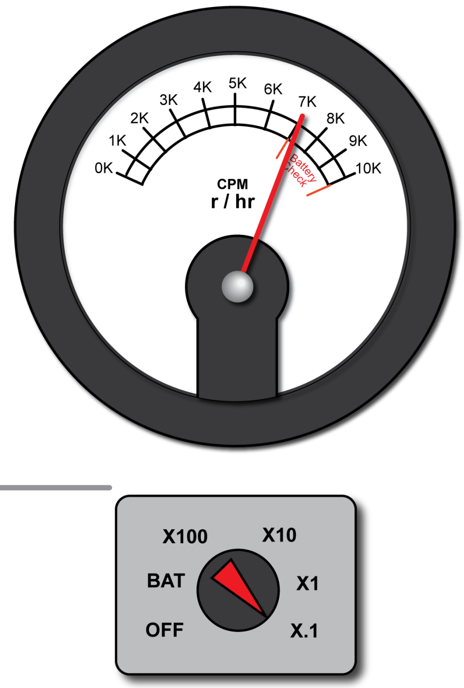
Frisking procedures:

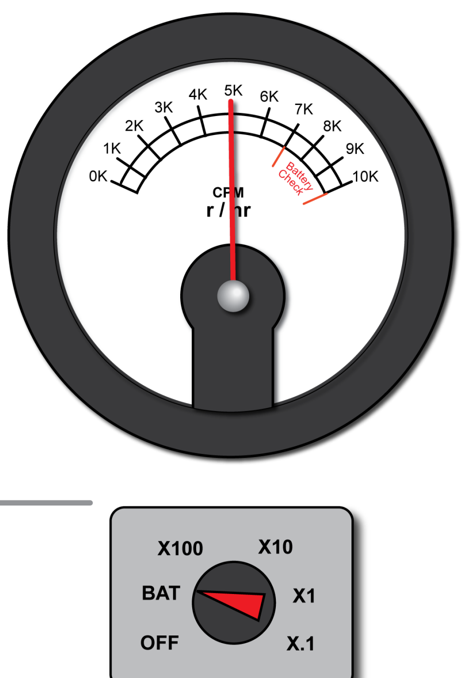
1. Have the individual being monitored stand on a step off pad. This reduces the possibility of contaminating the monitoring site.
2. Verify the instrument is on, set to the proper scale (x1 scale), and ensure the audio can be heard.
3. Place the survey meter probe about 1/2 inch from the individual's body, being careful not to make body contact.
4. Instruct the person to stand straight, feet spread slightly, arms extended with palms up and fingers out straight.
5. Monitor hands and arms, then repeat with hands and arms turned over.
6. Starting at the top of the head, cover the entire front of the body, monitoring carefully the head, neckline, trunk, legs, crotch, and armpits.
7. Have the individual turn around and repeat the monitoring on the backside of the body.
8. Monitor the shoes and soles.

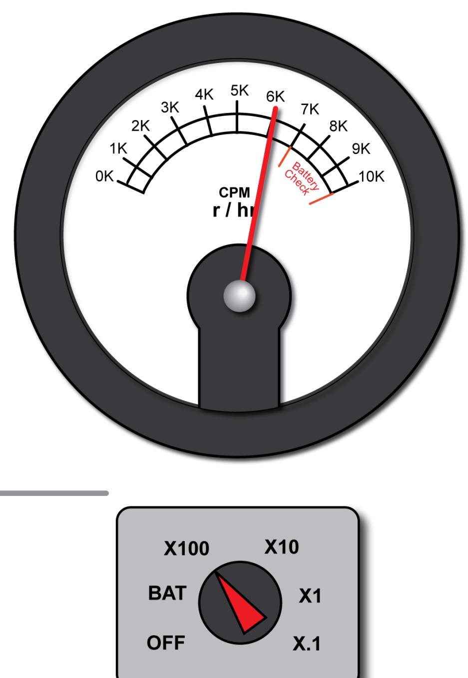
Station 4:

Task 1: Identify the correct readings for the radiation survey meter as outlined below and record your answers:









Task 2: Write an appropriate definition for the following types of contamination and state whether or not an Operating Engineer would encounter it and where:

Removable contamination

Fixed contamination

Airborne contamination

Waterborne contamination

Internal contamination

Decontamination

Decontamination (decon) is the removal of radioactive materials from locations where it is not wanted. If removable contamination is discovered, decontamination is the normal means of control. You will have to go through a decontamination procedure if you work in an area where you are likely to become contaminated. A good example of this for Operating Engineers is moving contaminated soil or demolishing contaminated structures. You may also have to decontaminate your equipment if it must be removed from the radiation contamination area for any reason.

Personnel decontamination

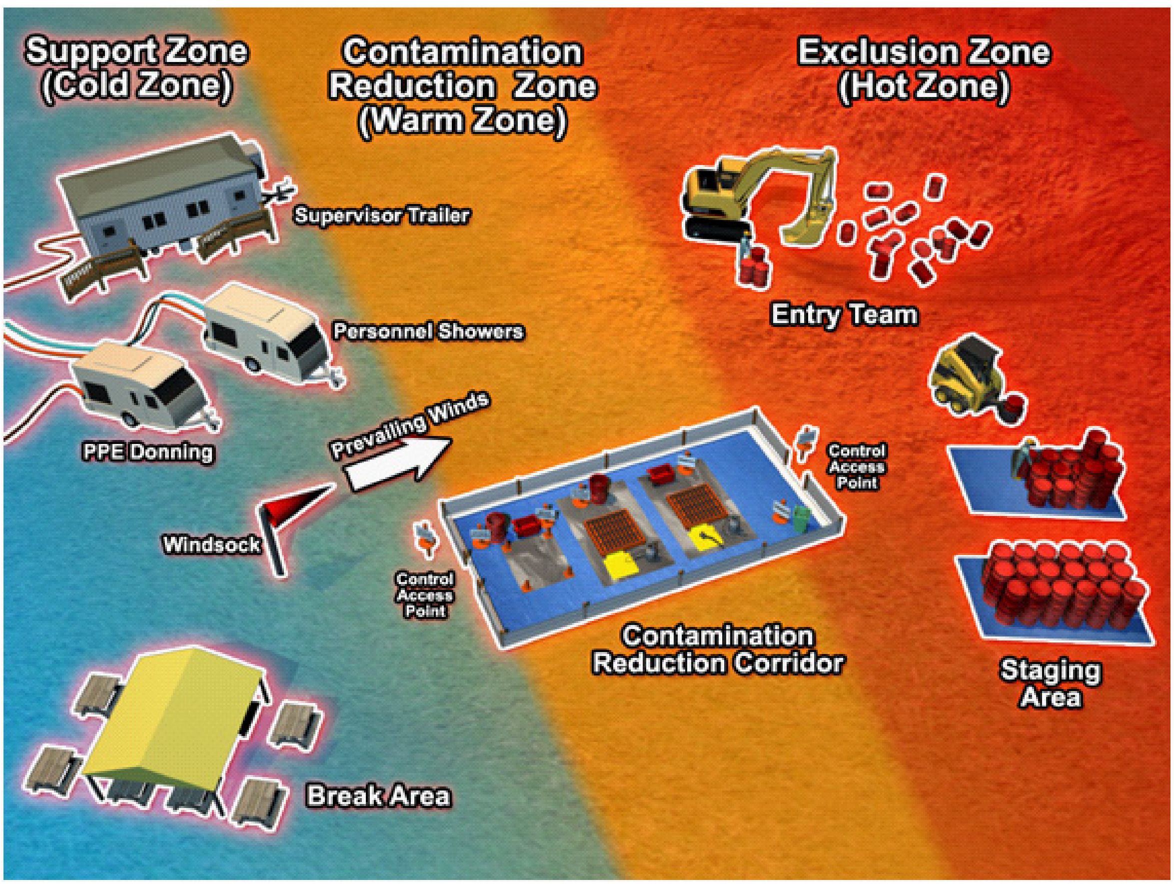
Personnel decontamination is normally accomplished using mild soap and lukewarm water per Radiological Control Organization instructions. More aggressive decontamination techniques are performed under the guidance of the Radiological Controls Organization. The idea of decon is to ensure that as you are leaving the contamination area, you are becoming less contaminated. This is accomplished by setting up contamination reduction zones. Each zone includes stations for removing contamination as the worker moves down the line away from the contamination area. You can think of the contamination area as the “Hot” zone; while the decon area is the “warm” zone. Once you have gone through the decon line and have been frisked in your clothing, you move into what is called the “cold” zone; which is the area free of all contamination. Conducting the decon process, either as a worker exiting the contamination area, or as a worker performing the decon (or self decon), takes practice. Your site will have a specific decon procedure that must be followed.

Alternate Names for Work Zones

Hot Zone – Exclusion Zone
Warm Zone – Contamination Reduction Zone
Cold Zone – Support Zone

Enter site decon procedure details in the space provided below:

An example of a basic work zone layout and what a basic decon line may look like is provided below.



Equipment and area decontamination

Equipment and area decontamination is the removal of radioactive materials from tools, equipment, floors, and other surfaces in the work area. This can be quite the task for heavy equipment! There will be an equipment decon station set up to collect the wash material run-off and to ensure that it does not contaminate the surrounding environment. An example is shown below:

Workers decontaminate heavy equipment after creating the decon station from common materials such as plastic barrier, cinder blocks, and railraod ties.

NOTE: In some situations, decontamination is not possible, as with the following examples:

- **Economic considerations:** Cost of time and labor to decontaminate the location may outweigh the hazards of the contamination present

- **Radiological conditions:** Radiation dose rates or other radiological conditions may present hazards that exceed the benefits of decontamination. The decontamination activity may not be ALARA, in that it costs, rather than saves personnel dose.
- **Hazardous conditions:** The physical or chemical conditions in the area may prevent entry for decontamination purposes

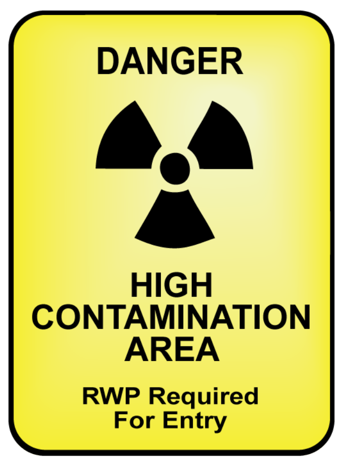
Objective 5: Define "Contamination," "High Contamination," and "Airborne Radioactivity Areas"

Definitions and posting requirements

Contamination Area

A Contamination Area is an area where removable contamination levels exceed or are likely to exceed the limits specified in 10 CFR 835 Appendix D, but do not exceed 100 times these levels. Posting requirements include:

"CAUTION, CONTAMINATION AREA"



High Contamination Area

A High Contamination Area is an area where contamination levels exceed or are likely to exceed 100 times the Contamination Area limits. Posting requirements include:

"DANGER or CAUTION, HIGH CONTAMINATION AREA"

Additionally, the posting may state:

"RWP REQUIRED FOR ENTRY"

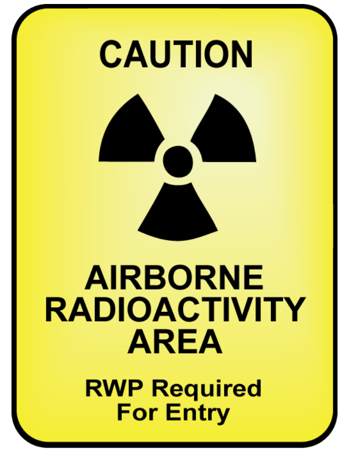
Airborne Radioactivity Area

An Airborne Radioactivity Area is an area where airborne radioactivity exceeds specified limits. Posting requirements include:

“CAUTION OR DANGER, AIRBORNE RADIOACTIVITY AREA”

Additionally the posting may state:

“RWP REQUIRED FOR ENTRY”



Objective 6: Identify the minimum requirements for entering, working in, and exiting Contamination, High Contamination, and Airborne Radioactivity Areas

Contamination Area

Minimum requirements for entering Contamination, High Contamination, and Airborne Radioactivity Areas without an escort are as follows:

- Radiological Worker II training
- Personnel dosimetry, as appropriate
- Protective clothing and respiratory protection as specified in the RWP
- Worker’s signature on the RWP, as applicable
- Pre-job briefings, as applicable

Insert facility/site-specific information in the space provided below:

High Contamination Area

Minimum requirements for working in Contamination, High Contamination, and Airborne Radioactivity Areas are as follows:

- Avoid unnecessary contact with contaminated surfaces
- Secure equipment (lines, hoses, cables, etc.,) to prevent them from crossing in and out of contamination areas
- When possible, wrap or sleeve materials, equipment, and hoses
- Place contaminated materials in appropriate containers when finished
- Do not touch exposed skin surfaces. High levels of skin contamination can cause a significant skin dose. It may also lead to internal contamination with radioactive material.
- Avoid stirring contamination as it could become airborne
- Do not smoke, eat, drink, or chew. Do not put anything in your mouth.
- Exit immediately if a wound occurs or if your protective clothing is compromised (e.g., becomes wet, torn, or otherwise compromised)

Enter facility/site-specific information in the space provided below:

Airborne Radioactivity Area

Minimum requirements for exiting Contamination, High Contamination, and Airborne Radioactivity Areas are outlined below:

- Exit only at step-off pad
- Remove protective clothing carefully. Follow posted instructions.
- Frisk or be frisked for contamination when exiting a contaminated area. If personal contamination is found, stay in the area, notify the Radiological Control Technician, and minimize the potential for cross contamination
- Survey all tools and equipment prior to removal from the area

- Observe RWP and control point guidelines
- Use proper techniques to remove protective clothing
- Do not smoke, eat, drink, or chew
- Do not put anything in your mouth
- When exiting, perform a whole-body frisk at the location provided by the Radiological Control Organization. If personal contamination is found, stay in the area, notify the Radiological Control Technician, and minimize the potential for cross-contamination (e.g., place a glove over a contaminated hand.)

The steps for properly exiting a Radiological Buffer Area are outlined in the images below.

1. Understand site-specific guidlines. Survey tools and equipment prior to removal from the area. Prepare to exit only at the step-off pad.

2. Return tools to designated containers for decontamination.

3. Use proper techniques to remove protective clothing. Dispose of suits, gloves, hardhats, and respirators as designated.

4. Frisk or be frisked for contamination when exiting a contaminated area. If personal contamination is found, stay in the area, notify the Radiological Control Technician, and minimize the potential for cross contamination.

Lessons Learned

Insert facility/site-specific information on lessons learned concerning contamination control in the space provided below:

Summary

Your jobs as Operating Engineers include conducting radiological work. This work will place you inside contamination areas, where you are more than likely going to disturb contaminated materials (e.g., dirt.) It is imperative that you understand and follow contamination control procedures. Procedures such as using engineering controls, using PPE, using personal contamination detectors and decon procedures. These procedures will allow you to reduce the spread of contamination and help to keep you and your co-workers safe on the job!

Oak Ridge National Laboratory - Contamination Reduction Zone/ Exclusion Zone for Mixed Waste Tank 7860A Excavation - New Hydrofracture Facility. Courtesy DOE.

Review questions

1. Draw lines to match the term with the definition.

Contamination that can be transferred by casual contact.	Fixed contamination
Contamination suspended in the air.	Removable contamination
Contamination that cannot be readily removed from surfaces.	Airborne contamination

2. Which of the following are sources of radioactive contamination (check all that apply)?

__ Poor housekeeping

__ Receiving an X-ray

__ Excessive movement in contamination areas

__ Leaks or breaks in radioactive systems

__ Over exposure to sunlight

3. The first action an employee should take for a spill of radioactive material is

____.

4. The three general methods to control radioactive contamination are

____,

____, and

____.

5. Protective clothing must be ____________________ prior to use

6. While frisking with a Beta-Gamma frisker the probe should be held ___________

inch or less from the surface and moved at a rate of not greater than

_________ inches per second.

7. The Alpha probe must be held within _______ inch from the surface.

8. Personnel decontamination is normally accomplished by:

A. Scrubbing with a wire brush

B. Using acid-based chemicals

C. Using mild soap and lukewarm water

D. Using mild soap and hot water

9. An area where contamination levels are 100 greater than the Contamination Area limits is called a/an:

A. High Radiation Area

B. Very High Radiation Area

C. Airborne Radioactivity Area

D. High Contamination Area

10. A worker must have completed which of the following trainings to enter a Contamination Area?

A. GERT

B. Radiological Worker I

C. Radiological Worker II

D. HAZWOPER

Notes:

Notes:

Module 10: Radiological Emergencies

Objectives

At the end of this module, you will have an understanding of the following:

- State the purpose and types of emergency alarms and the correct responses to them
- State the possible consequences of disregarding radiological alarms
- State the site administrative emergency radiation dose guidelines

Purpose of the module

This module discusses off-normal and emergency situations and the appropriate response to each situation. Radiological alarms associated with monitoring equipment will also be discussed. Various radiological monitoring systems are used to warn personnel if abnormal radiological conditions exist. Radiological workers must become familiar with these alarms and know the appropriate response. These responses will help to minimize exposure and personal contamination during off-normal conditions.

Radiological workers perform a drill in which victims are to be safey removed from a fictitious high-risk area. Courtesy of IAEA.

Objective 1: State the purpose and types of emergency alarms and the correct response to them

Equipment that monitors for unusual radiation levels and airborne radioactivity is placed in strategic locations in some facilities. It is essential that each worker be able to identify the equipment and alarms, and respond appropriately to those alarms. Workers should also be familiar with the locations of exits and fire extinguishers. Because of the variety of alarm systems at different facilities, more detailed information must be covered during facility specific training.

Emergency alarms and responses

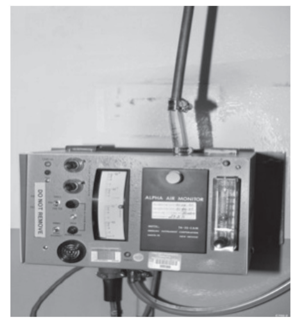
Devices that monitor for abnormal radiation dose rates and airborne contamination levels are placed in strategic locations throughout facilities. It is essential for the worker to be able to identify the equipment and alarms and respond appropriately to each. Each DOE facility is equipped with radiation detection alarms which are designed to give audible and visible warnings if radiation or contamination levels go above a specified level. It is important that you understand the alarms in your facility, and know what action to take if an alarm sounds or if an emergency occurs. The specific types of alarms vary from facility to facility. The following are descriptions of some of the common types of emergency radiation detection alarms.

Area Radiation Monitors

Example of a RAM.

The remote area monitor (RAM) may also be called the area radiation monitor (ARM). This is a fixed location detector attached to a wall or other support. It monitors radiation levels in the area around the device. The alarm is activated if high radiation levels are detected. The alarm usually has a flashing red light, as well as a loud, fast sounding bell. If a RAM (ARM) goes off, evacuate the area and notify your supervisor and the Radiological Control Organization. Follow any additional site-specific procedures. List any site-specific procedures to a RAM in the space provided below.

Continuous Air Monitors



Example of a CAM, courtesy DOE.

Continuous air monitor (CAM): A CAM measures airborne radioactivity levels. The instrument continuously samples the surrounding air. It collects airborne dust on a filter, and then measures any radioactivity on the filter. The CAM also has a flashing red light and a fast sounding bell. Most CAM's monitor for beta and gamma radiation, but there are some CAM's that can also detect alpha emitters in airborne dust. If a CAM goes off, evacuate the area and notify your supervisor and the Radiological Control Organization. Follow any additional site-specific procedures.

CAM emergency response procedure:

1. Secure your work area
2. Exit the area, room, or building using proper radiological controls
3. Notify Radiological Control of the alarm
4. Stand fast in the general vicinity, but outside of the affected area

List any site-specific procedures to a CAM in the space provided below.

Criticality alarm

CANBERRA EDAC21 Criticality alarm system.

A criticality alarm detects unusually high levels of gamma and/or neutron radiation to warn of a possible criticality accident. This alarm is a continuous, shrill sound from a clarion horn along with a red flashing or revolving light. The criticality alarm is only installed in buildings where a criticality radiation accident could happen. If a criticality alarm sounds, evacuate immediately. Follow the site-specific evacuation procedures.

Criticality alarm emergency Response Procedure:

1. Stop whatever you are doing and leave the building immediately by the nearest exit.
2. Get to paved roads and follow them to the assembly area assigned for your facility.
3. Walk quickly, but do not run. Do not stop until you reach the assembly area.
4. Once you reach the assembly area you must:
   - Report in to your supervisor or whoever is doing the accountability for your group
   - Report anything unusual you may have seen
   - Remain in the assembly area
   - No eating, drinking, chewing, or smoking

Record any site-specific procedures to a criticality alarm in the space provided below.

Other responses during emergencies

Working in a radiological environment requires more precautionary measures than performing the same job in a non-radiological setting. If an emergency arises during radiological work, response actions may be necessary to ensure personnel safety.

Injured personnel

There may be personnel injuries in areas controlled for radiological purposes. If this happens, there should be a facility or site procedure for how to respond. Fill in the site-specific response information for injuries in controlled radiological areas in the space provided below.

Situations that require immediate exit from an area controlled for radiological purpose

Some situations may require workers to immediately exit a radiologically controlled area. These could be a spill of radioactive material or a spill of other hazardous material. No matter what the situation, a procedure should be outlined in the site-specific response plan.

Ambulance from Fernald Closure Project. Fernald, OH. Courtesy DOE.

For an accidental breach of a radioactive system or a spill of radioactive material enter the site-specific procedure in the space provided below.

For radioactive spills involving highly toxic chemicals, workers should immediately exit the area without attempting to stop or secure the spill. They should then promptly notify Industrial Hygiene or the Hazardous Material team and Radiological Control personnel.

Objective 2: State the possible consequences of disregarding radiological alarms

To protect yourself and your co-workers, it is imperative that you understand and follow all radiological alarms and emergency procedures. If you do not comply with alarms, unintended and potentially dangerous consequences can occur. Disregarding any of these radiological alarms may result in:

- Excessive personnel radiation dose
- Unnecessary spread of contamination
- Unnecessary personal contamination
- Disciplinary action

Objective 3: State the site administrative emergency radiation dose guidelines

Working in a radiological environment requires more precautionary measures than performing the same job in a non-radiological setting. If an emergency arises during radiological work, additional precautions may be necessary. Emergency situations can involve:

- Personnel injuries in areas controlled for radiological purposes
- Situations that require immediate exit from an area controlled for radiological purposes
- An accidental breach of a radioactive system or spill of radioactive material

DOE uses the word “SWIMS” as a way to remember the correct response to an emergency situation in a radiologically controlled area:

- Stop or secure the operation causing the spill
- Warn others in the area, notify Radiological Control Personnel
- Isolate the spill area if possible
- Minimize individual exposure and contamination
- Secure unfiltered ventilation (fans, open windows, etc.)

In extremely rare cases, emergency exposure to high levels of radiation may be necessary to rescue personnel or to protect major property. Rescue and recovery operations that involve radiological hazards can be a very complex issue with regard to the control of personnel exposure. The type of response to these operations is generally left up to the official in charge of the emergency situation. The official’s judgment is guided by many variables that include determining the risk versus the benefit of the action, as well as how to involve other personnel in the operation. Rescue actions that might involve substantial personal risk shall be performed by volunteers. The use of volunteers will be based on their age, experience, and previous exposure. All personnel selected to provide emergency response shall be trained commensurate with the hazards in the area and required controls. They shall be briefed beforehand on the known or anticipated hazards to which they shall be subjected.

The DOE guidelines for control of emergency exposure are outlined in Table 10.1 below.

Table 10.1: Guidelines for control of emergency exposures		
Dose limit (whole body)	**Activity performed**	**Conditions**
5 rem	All activities	Where lower dose limit is not practicable
10 rem	Protecting major property	Where lower dose limit is not practicable
25 rem	Lifesaving or protection of large populations	Where lower dose limit is not practicable
>25 rem	Lifesaving or protection of large populations	Only on a voluntary basis to personnel fully aware of the risks involved
1 The lens of the eye dose guideline is three times the listed values. The shallow dose guideline to the skin of the whole body and the extremities is 10 times the listed values. These doses are in addition to and accounted for separately from the doses received under the limits in §§835.202 and 835.205.		

Site administrative emergency dose guidelines for rescue and recovery operations may be recorded in the space provided below.

Summary

By following your work sites emergency response procedures you and your co-workers will increase your chances of bringing an emergency situation to a close without injury. If emergency response is something that interests you, check with your supervisor or the IUOE National Hazmat Training Program to ask about getting the proper emergency response training so that you could become part of an emergency response team.

Lehigh Valley International Airport Transportation Emergency Preparedness Program Exercise - Accident Scene Responder Decontamination Operation. Cortesy DOE.

Review questions

1. List the correct response to a continuous air monitor alarm.

2. Radiation monitors are normally used to detect airborne radioactivity.

True______ False_____

3. Define the letters in the following acronym:

S ____

W ____

I ____

M ____

S ____

4. Which of the following requires immediate exit from a radiological area?

a. Off-scale Direct Reading Dosimeter (DRD)

b. A tear in the anti-C coveralls

c. A lost or damaged TLD

d. All of the above

5. List the DOE and site administrative occupational emergency radiation dose limits for:

Protecting major property: ____

Lifesaving or protection of large populations: ______________________________

Lifesaving (voluntary basis): ____

Notes:

Notes:

Glossary: Radiological Terms, Abbreviations, and Acronyms

Radiological Terms

Abnormal situation: An unplanned event or condition what adversely affects, potentially affects or indicates degradation in the safety, security, environmental or health protection performance or operation of a facility.

Activation: The process of producing a radioactive material by bombarding a nonradioactive material with neutrons, protons or other nuclear particles.

Acute dose: A large radiation dose received over a short period of time.

Acute effect: A health effect which occurs soon after a relatively high dose of ionizing radiation. For example, changes in blood cells may occur after an acute dose of 10 to 15 rem. Radiation sickness may occur after an acute dose of 100 rem.

Acute radiation syndrome: A condition which results from a very large acute dose of ionizing radiation. Symptoms include hair loss, nausea, vomiting and spasms.

Administrative control level: A radiation dose level which is lower (more protective) than the dose limit established by DOE regulations. The purpose is to maintain exposure below the regulatory limits. There are two types of administrative control levels: A DOE administrative control level is set by DOE. A facility administrative control level is set by the facility. [See the Summary of Radiation Dose Limits and Control Levels under Radiation dose limit later in this Glossary.]

Airborne contamination: Radioactive material that is in the air. This includes radioactive gases and vapors, or radioactive particulates such as dusts, powders, mists or sprays.

Airborne radioactivity: Another name for airborne contamination.

Airborne radioactivity area: An area designated as having a concentration of airborne contamination which is higher than the natural background by at least 10 percent of the derived air concentration (DAC) during eight hours, or a peak concentration of 1 DAC.

ALARA: As Low As Reasonably Achievable. The concept of keeping exposures as low reasonably achievable. ALARA is not a dose limit, but an ongoing process to keep exposures as low as reasonably achievable.

ALARA program: The program which the contractor is required to maintain in order to assure that radiation doses are not just below the required levels, but even lower: as low as reasonably achievable. The ALARA Program includes an ALARA committee, and ALARA goals. The ALARA Program is a fundamental requirement of every radiological control program.

ALARA committee: The ALARA Committee shall include managers, workers, technical support personnel and representatives of the radiological control organization. The ALARA Committee: 1) Makes recommendations to management to improve progress toward minimizing radiation exposure and releases of radioactive material; 2) Evaluates construction and design plans, major modifications of work activities, and plans for waste and release minimization; 3) Receives and reviews audits of the Radiological Control Program; and 4) Reviews the overall conduct of the Radiological Control Program.

Alpha particle (α): A charged particle emitted at a very high velocity from the nucleus of a radioactive atom. An alpha particle consists of two protons and two neutrons. It has a mass of four atomic mass units and a positive charge of two (+2).

Alpha radiation (α): Ionizing radiation in the form of alpha particles. Alpha radiation is an internal radiation hazard. Because alpha radiation cannot penetrate the dead layer of skin cells on the surface of the body, it is not an external radiation hazard. Alpha radiation has a range in air of only one or two inches because it quickly deposits its energy as it collides with air molecules.

Annual limit of intake (ALI): The quantity of a single radionuclide which, if inhaled or ingested in one year, would cause radiation exposure equal to the annual dose limit (5 rem per year).

Anti-C clothing (anti-contamination clothing): Protective clothing, usually made of cotton or other fabric in a canary yellow color, and intended to reduce or prevent contact with radioactive contamination.

Area radiation monitor: A device mounted in a radiation area which measures the level of ionizing radiation and which sounds an alarm if abnormal levels occur. Atom: The smallest piece or unit of an element. An atom consists of a nucleus surrounded by an electron cloud. The nucleus contains one or more protons. The nucleus of each atom except normal hydrogen also has one or more neutrons.

Background radiation: Radiation from naturally occurring sources including: 1) Cosmic radiation from outer space; 2) Radiation from uranium and other naturally occurring elements in the earth's crust (terrestrial radiation); 3) Radon gas in the atmosphere; and 4) Radioactive elements incorporated within our own bodies (internal radiation).

Becquerel (Bq): A measurement unit for the activity of radioactive material. One Becquerel is that quantity of radioactive material in which one atom disintegrates per second. 37 billion Bq = 1 Curie.

Beta particle (β): A charge particle emitted at great velocity from the nucleus of a radioactive atom. A beta particle is the same size and weight as an electron, and usually has a charge of minus one (-1). Beta particles are sometimes referred to as fast moving electrons, although they come from the nucleus, not from the atom's electron cloud. A beta particle with a positive charge (+1) is called a positron.

Beta radiation (β): Ionizing radiation made up of beta particles. Beta radiation is an internal hazard if radioactive material which emits beta radiation is absorbed into the body. Beta radiation can penetrate the first few layers of skin cells. This makes it an external hazard to the skin and eyes. Beta radiation has a range of several inches in air.

Bioassay: A measurement of the amount of radioactive material deposited in the human body, or excreted from the body. Examples of bioassays are whole-body counting, organ counting, urine analysis, fecal analysis and analysis of other biological specimens.

Biological effect: An effect that may occur in a cell as the result of exposure to ionizing radiation. Generally the effect is caused by ionization of atoms in biological molecules within the cell. Biological effects include both acute effects and chronic effects. Biological effects are also called "health effects."

Calibration: The process of adjusting a measuring or monitoring instrument by comparing its reading to a known standard.

Carcinogen: A chemical or physical agent which can cause cancer. Ionizing radiation is known to cause certain kinds of cancer. Ionizing radiation is a carcinogen.

Cell: The basic unit of all living organisms.

Cell membrane: The surface or wall that surrounds and encloses a cell.

Cell nucleus: A structure inside of a cell containing the cell's chromosomes.

Chromosome: A structure within the cell's nucleus that contains the cell's genetic material (DNA), and which transmits genetic information when the cell divides to form two new cells.

Chronic dose: A radiation dose received over a long period of time.

Containment device: A barrier such as a glovebag, glovebox or tent used to inhibit the release of radioactive material from a specific location.

Contamination area (CA): An area where the amount of radioactive contamination is enough to create radiation levels greater than the values given in Table 2-2 of the DOE Radiological Control Manual (DOE N-5480.6), but less than or equal to 100 times those values. Note that there are different values for different radionuclide contaminants. Table 2.2 is reproduced in Appendix C. Note that if the levels are greater than 100 times the Table 2.2 values, then it is a High Contamination Area.

Contamination survey: The use of swipes, smears, or direct instrument surveys to identify and measure radioactive material on people, equipment, surfaces or areas.

Continuous airmonitor (CAM): An instrument that continuously measures the levels of airborne radioactive material in an area on a "real time" basis, and is designed to sound an alarm if the concentration of radioactive material reaches a preset level.

Controlled area: An area, room, building, etc. to which access is controlled in order to protect personnel from exposure to radiation of contamination from radioactive materials.

Cosmic radiation: Cosmic radiation which reaches the earth from outer space. Most cosmic radiation is absorbed in the atmosphere, but some reaches the surface of the earth where it is part of the natural background radiation to which we are all exposed. Cosmic radiation exposure is greater at higher altitudes.

Counts perminute (cpm): A unit for measuring radioactivity. Counts per minute is the response of a survey meter or other measuring device. Counts per minute (cpm) is not usually the same thing as disintegrations per minute (dpm), because the meter is generally less than 100% efficient, which means that it does not count every disintegration. cpm/efficiency = dpm.

Criticalmass: The smallest amount (mass) of fissionable material that will support a self-sustaining nuclear chain reaction under specified conditions.

Curie (Ci): A unit of measurement for the activity of radioactive material. 1 Ci = 37 billion disintegrations per second. 1 Ci = 37 billion Bq. 1 Ci = 2,200 billion dpm.
Declared pregnant worker: A woman employee who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception.

Decontamination: The process of removing radioactive material from people, equipment, surfaces and areas.

Derived air concentration (DAC): The concentration of a radioactive nuclide in the air (airborne radioactivity) that, if breathed in over the period of one year, would result the Annual Limit on Intake (ALI) for that radioactive nuclide being exceeded. The DAC is obtained by dividing the ALI by the volume of air breathed by an "average" worker, at work, during one year (2400 m3).

Distance: A method of reducing exposure to ionizing radiation by increasing the distance between the radiation source and the worker.

Disintegrations per minute (dpm): A unit for measuring the activity of radioactive material. 60 dpm = 1 disintegration per second, or 1 Bq. Disintegrations per minute equals counts per minute divided by the efficiency of the survey meter.

DOE: The United States Department of Energy.

DOE activity: An activity taken for or by DOE that has the potential to result in the occupational exposure of an individual to radiation or radioactive material. The activity may be, but is not limited to, design, construction, operation, decontamination or decommissioning. To the extent appropriate, the activity may involve a single DOE facility or operation or a combination of facilities and operations, possibly including an entire site.

Dose (radiation dose): In common speech, radiation dose refers to the amount of mrems or rems of ionizing radiation you receive. Note that this is technically incorrect, since mrem and rem measure dose equivalent, not dose. However, it is simpler to just say "dose" instead of "dose equivalent." Technically, radiation dose is the amount of energy deposited in body tissue due to radiation exposure. Radiation dose, in this sense, is measured in rads and millirads, or in grays. To convert from dose (rads, millirads, grays) to dose equivalent (rems, millirems, sieverts), multiply by the quality factor for the particular type of radiation. There are several different "dose" terms used to describe the interaction of ionizing radiation with tissue and to describe the radiation exposure of individuals and populations. For more information see Appendix A.

Dose assessment: The process of determining the radiation dose received by a person or a community through the use of monitoring data, bioassay results, estimates based on exposure scenarios, pathway analysis, etc.

Dose equivalent: A measure of the biological effect of radiation that is absorbed by the body. Dose equivalent is measured in mrem and rem, or in sieverts. Mathematically, dose equivalent in rem or millirem is calculated by multiplying the dose in rads or millirads by a "quality factor" which takes into account the biological effectiveness of the type of ionizing radiation involved. (Dose equivalent in sieverts is calculated by multiplying the dose in grays by the appropriate quality factor.)

Dose rate: The rate at which a person receives a radiation dose. Usually we are referring to the "dose equivalent" in mrem, but it is common practice to simply say "dose rate" instead of "dose equivalent rate." For example, the dose rate in a certain situation might be 100 mrem per hour. This means that if a person spent one hour under these conditions, he or she would receive a dose of 100 mrem. In one-half hour they would receive 50 mrem, etc.

Embryo/fetus: The developing human organism from the time of conception to the time of birth.

Electron: A negatively charged particle which orbits the nucleus of an atom.

Electron cloud: Another way of describing the "orbits" of the electrons around the nucleus of an atom.

Engineering controls: The control of radiation exposure and radioactive contamination through the use of ventilation systems, enclosures, piping, filtration devices, shielding, etc. This is in contrast to relying solely on personal protective equipment or good work practices to control exposures.

Entrance or access points: Any location through which a person could gain access to a radiologically controlled area. This includes entry or exit portals of sufficient size to permit human entry.

Extremities: The hands and forearms below the elbow, and the feet and lower legs below the knees.

External contamination: Radioactive contamination (materials) on the body or clothing, but not inside the body.

External dosimetry: Devices such as film badges, TLD's and pocket self-reading dosimeters worn on the body to measure exposure to external sources of radiation.

External exposure: Exposure to radiation from sources located outside of the body.

Film badge: A personnel monitoring device which used photographic film inside a badge to measure radiation exposure. When the film is developed, the darker the film, the greater the exposure.

Finger ring: A piece of thermoluminescent material encased in a ring that is worn on the finger as a way to monitor for radiation exposure to the hand (extremities).

Fixed contamination: Radioactive material that cannot be removed readily from surfaces by casual contact, wiping, brushing or washing.

Fixed contamination area: An area which contains no removable contamination, but contains fixed contamination exceeding specified limits.

Frisk, frisking: The process of monitoring a person to determine whether they are contaminated with radioactive material. Frisking can be performed using a hand-held survey instrument, an automated monitoring device such as PCM, or by Radiological Control Personnel.

Gamma radiation (γ): Ionizing radiation in the form of gamma rays. Gamma radiation has high penetrating power, so that it is an external radiation hazard. If radioactive material that emits gamma radiation gets into the body, then the gamma radiation is also an internal hazard.

Gamma ray (γ): A ray of pure energy emitted from the nucleus of certain radioactive atoms.

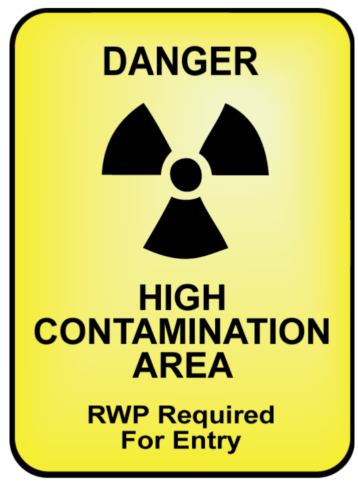
Gene: A small section of DNA containing the genetic information for a particular trait.

Genetic effect: A biological effect on the genetic material (DNA) in a cell. This effect causes changes in other cells produced by that cell. This is also called a mutation. Note that a genetic effect can occur in any cell of the body. If the effect occurs in a cell involved in human reproduction (a sperm or an egg), it is called a heritable effect. This might lead to an adverse reproductive effect. If a genetic effect occurs in a cell which is not involved in human reproduction, it is called a somatic effect. This might lead to cancer.

Gestation period: The time from conception to birth, approximately nine months.

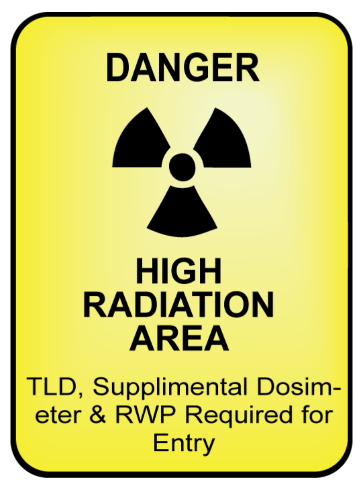
Gray (Gy): A new unit for measuring absorbed radiation dose. 1 gy = 100 rad.

HEPA filter (high efficiency particulate air filter): A filter that can remove tiny particulates from the air. HEPA filters are used in respirators and in ventilation filtration systems. The technical specification for a HEPA filter is that it is capable of removing 99.97% of particulates having an average diameter of 0.3 micrometers (millionths of a meter).



Heritable effect: A genetic effect that occurs in the reproductive cells (sperm or eggs) and is inherited from a parent or passed on to a child.

High contamination area: An area where the contamination levels are greater than 100 times the values given in Table 2-2 of the DOE Radiological Control Manual (DOE N-5480.6). Note that there are different values for different radionuclide contaminants. Table 2.2 is reproduced in Appendix C. See also the definition of Contamination Area.



High radiation area: An area where radiation dose rates are greater than 100 mrem per hour, but less than 500 rad per hour. Hot particle: A very small piece of nuclear fuel or radioactive material corrosion product which has a high level of radioactivity as the result of nuclear fission or neutron activation. The word “particle” here refers to a piece of material in the form of a dust or powder. Don’t confuse this with the use of the word “particle” to describe the individual parts of an atom (proton, neutron and electron) or the types of particulate radiation (alpha, beta and neutron).

Hot spot: A localized source or radiation caused by the presence of radioactive material sufficient to cause radiation exposure at least 5 times higher than the surrounding area, and at a dose rate of at least 100 mrem per hour.

Internal contamination: Radioactive material that has gotten into the body by one or more routes of entry (inhalation, ingestion, skin absorption or entry through a wound.

Internal exposure: Exposure to radiation from radioactive materials which have been inhaled, ingested, absorbed through the skin or have entered through a wound.

Internal radiation: Radiation from radioactive materials which have been inhaled, ingested, absorbed through the skin or have entered through a wound.

Inverse Square Law: According to the inverse square law, radiation spreads out as it travels away from the radiation source. The intensity is inversely proportional to the distance from the source. The following formula demonstrates the inverse square law where the source intensity (I_1) from at least one distance (D_1) has been determined:

$$\frac{I_1}{I_2} = \frac{{D_2}^2}{{D_1}^2}$$

Ion: An atom which has lost or gained one or more electrons. An ion is not electrically neutral. If it has lost an electron, then it has less negative charge than positive charge, which means it has a net positive electric charge. On the other hand, if it has gained an electron, then it has a net negative charge.

Ionization: A process by which one or more electrons is removed from an atom. Radiation that has enough energy to cause ionization is called ionizing radiation.

Ionizing radiation: Energy, in the form of a wave or a fast moving particle, which is capable of ionizing an atom.

Isotopes: Atoms which have the same number of protons (so they are the same element), but have a different number of neutrons.

Low level radioactive waste: Radioactive waste that is not classified as high-level waste, transuranic waste, spent nuclear fuel or by-product material.

Millirem (mrem): One one-thousandth (1/1000) of a rem. A unit for measuring the dose equivalent of radiation absorbed by tissue.

Mixed Waste: Waste containing both radioactive and hazardous chemical components.

Neutron: One of the basic particles found in the nucleus of an atom. It is called "neutron" because it is electrically neutral (has no electrical charge)

Neutron radiation: Ionizing radiation consisting of neutron particles produced during the fission process in a nuclear reactor or particle accelerator. Neutron radiation has a high penetrating ability and require shielding material that has a high hydrogen content, such as plastic or water.

Non-ionizing radiation: Radiation such as radio waves, micro waves, radar, infrared, visible light, or ultra violet that does not have enough energy to ionize atoms.

Nuclear criticality: An event in which radioactive material undergoes a selfsustainingnuclear chain reaction.

Nuclear Regulatory Commission (NRC): Federal agency that regulates civilian nuclear power plants.

Nucleus: 1. The core of an atom, where protons and neutrons are found. If the nucleus is unstable, then the atom is radioactive. The nucleus of a radioactive atom is the source of ionizing radiation in the form of alpha, beta or neutron particles, or gamma rays. -OR- 2. The part of a living cell that contains the genetic material DNA.

Occupational dose: The amount of an individual's dose due to exposure to ionizing radiation (both external and internal) as a result of that individual's work assignment. By definition, occupational dose does not include planned special exposures, exposure received as a medical patient, background radiation, or voluntary participation in medical research programs.
Personal contamination monitor: A monitor that detects radiation emitted from contamination on the body.

Personal monitoring: A systematic and periodic estimate of the radiation dose received by personnel during working hours. Also, the monitoring of personnel, their excretions, their skin or any part of their clothing to determine the amount of radioactive contamination present.

Personal protective equipment: Any safety equipment worn by the worker and designed to protect the worker against hazards. Examples include respirators, gloves, protective clothing (anti-c's), etc.

Planned special exposure: A pre-planned, infrequent exposure to radiation which is separate from, and in addition to the annual dose limits.

Prenatal radiation exposure: The exposure of an embryo/fetus to ionizing radiation.

Pocket alarm dose indicator (PADI): A small personal monitoring device with a digital display and an audible alarm.

Primary dosimeter: A dosimeter (often a TLD) worn on the body and used to obtain the formal legal record of whole body radiation dose.

Protective clothing: Clothing provided to personnel to minimize the potential for skin contamination or contamination of other personal or company issued clothing worn under the protective clothing. Protective clothing is also referred to as anticontamination clothing, anti-c's or PC's.

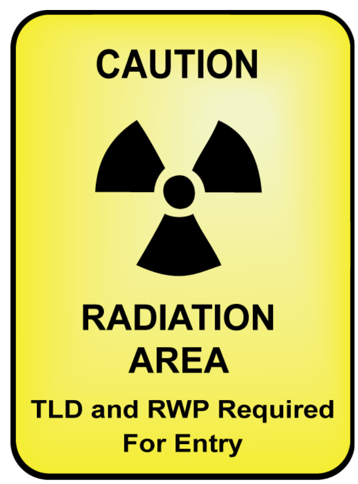
Proton: A positively charged particle located in the nucleus of the atom.

Public: Any individual or group of persons who is not occupationally exposed to radiation or radioactive material. A person is not considered a "member of the public" during any period in which the person receives an occupational dose.

Quality factor (QF): A number indicating the biological effect of a particular type of ionizing radiation. When radiation exposure (rads, millirads, grays) is multiplied by the quality factor, the product is the dose equivalent (rem, mrem, sievert).

Radiation: Energy that radiates out from a source. This includes both ionizing and non-ionizing radiation. Note that is this manual, "radiation" means "ionizing radiation" unless the context clearly indicates otherwise.

Radiation absorbed dose (rad): A measure of the amount of energy deposited in tissue when it is exposed to ionizing radiation.



Radiation area (RA): An area where dose rates are greater than 5 mrem per hour but less than 100 mrem per hour.

Radiation dose limit: A limit set by DOE regulations for the maximum radiation exposure that a person may receive under routine conditions. Both DOE and the facility contractors also set administrative control levels. [See the table below, and also see administrative control levels earlier in this Glossary.]

Summary of Radiation Dose Limits and Control Levels			
	DOE radiation Dose Limit	**DOE Administrative Control Level**	**Facility Administrative Control Level (2)**
Whole Body	5 rem / year	2 rem / year	
Extremities	50 rem / year	30 rem / year	
Skin and other organs	50 rem / year	30 rem / year	
Lens of the eye	15 rem / year	9 rem / year	
Embryo / fetus	500 mrem / year	(1) XXXXX	
Members of the public & minors	100 mrem/year	(1) XXXXX	

Notes: 1) XXXXXXXX indicates that the DOE Radiation Dose Limit applies. 2) Enter the Facility Administrative Control Levels for your facility.

Radiation dose rate: The rate at which an individual receives a dose of radiation, for example, mrem per hour. To calculate the total dose received, multiply the dose rate by the time. For example, 20 mrem per hour times 5 hours equals 100 mrem.

Radioactive: A word which describes an unstable atom when it emits ionizing radiation.

Radioactive contamination: Radioactive material in an unwanted place. Contamination may be in the form of a liquid, solid or gas. Remember that the words “radiation” and “contamination” do not mean the same thing. Contamination is a material. Radiation is a form of energy.

Radioactive decay: Radioactive decay is the process of radioactive atoms releasing radiation over a period of time. They do this in order to become stable (non-radioactive). Radioactive decay is also known as disintegration.

Radioactive half-life: Radioactive half-life is the time it takes for one half of the radioactive atoms present to decay.

Radioactive material: Any material containing (unstable) radioactive atoms that emit radiation.

Radioactivity: Radioactivity is the process of unstable (or radioactive) atoms trying to become stable. This is done by emitting radiation from the nucleus.

Radiological buffer area (RBA): An area which provides secondary boundaries to minimize the spread of radioactive contamination and to limit doses to general employees who have not been trained as radiological workers.

Radiological posting: A sign, marking or label that indicated the presence of radiation or radioactive materials, and which may indicate radiation levels and entry requirements.

Radiological work: Any work that requires the handling of radioactive material or which requires access to radiation areas, high radiation areas, contamination areas, high contamination areas or airborne radioactivity areas.

Radiological work permit (RWP): A document used to establish radiological controls for entry into radiologically controlled areas. The RWP informs workers of radiological conditions and entry requirements, and provides a record which relates workers' exposures to specific work activities.

Radiological worker: A worker who has the potential of being exposed to more than 100 mrem (1 millisievert) per year. A person who completes Radiological Worker I or Radiological Worker II training is considered a radiological worker. A radiological worker might also be called a radiation worker or radworker.

Radiologically controlled area: An area to which access is restricted because of the potential for radiation exposure or radioactive contamination.

Radiosensitivity: A term used to indicate the relative sensitivity of a particular organ to ionizing radiation.

Radon: A naturally occurring radioactive gas present in some soil and rocks. Radon gas can accumulate in unventilated areas such as basements. Radon is an alpha emitter.

Refresher Training: Training for radiological workers which is scheduled on the alternate year when full radiological worker retraining is not required.

Removable contamination: Contamination (radioactive material) that is easily transferred by casual contact, wiping, brushing, touching, washing or by air movement.
Respiratory protective equipment: Respirators used to protect personnel from the inhalation of radioactive materials or hazardous chemical substances.

Roentgen (R): A unit for measuring the intensity of gamma and x-radiation in air.
Roentgen equivalent man (rem): A unit used to measure the dose equivalence of radiation exposure. That is, the biologically effect of the exposure.

Sievert (Sv): A unit used to measure dose equivalent. One sievert equals 100 rems.

Sealed radioactive source: Radioactive material that is sealed into a container or capsule so that the material cannot escape under normal circumstances. A sealed radioactive source may emit radiation.

Self reading pocket dosimeter (SRPD): A direct reading device that provides an estimate of the current accumulated radiation dose. Also called a pocket ionization chamber (PIC), a direct reading dosimeter (DRD), or a quartz fiber (pocket) dosimeter.

Shielding: A method of reducing radiation exposure by placing a physical barrier which absorbs radiation between the source of radiation and the worker. The more penetrating the radiation is, the thicker or denser the shielding needs to be.

Soil contamination area: An area where surface or subsurface contamination levels exceed specified limits.

Somatic effect: Radiation effects that appear in non-reproductive cells of the exposed individual. Somatic effects can result in cancer.

Stay time: The length of time that a worker is allowed to remain in a radiation or high radiation area. Remaining in the area beyond the stay time may result in over exposure to radiation.

Step-off pad: An area between the contaminated and non-contaminated areas that is used to allow exit of personnel or removal of equipment.

Sticky pad: A step-off pad which has a tacky or sticky surface to reduce the potential for inadvertently tracking contamination out of the contaminated area.

Terrestrial radiation: Radiation from radioactive materials in the earth's crust.

Thermoluminescent dosimeter (TLD): A personal monitoring device that contains crystals that are sensitive to ionizing radiation enclosed in a plastic case.

Time: A method of reducing radiation exposure by limiting the time that a worker spends in a radiation area.

Unusual occurrence: A non-emergency occurrence that has significant impact or potential for impact on safety, environment, health, security or operations.

Very high radiation area (VHRA): An area where radiation exposure is greater than 500 rads per hour.

Waterborne contamination: Radioactive material in water.

Whole body counter: A device used in the laboratory to measure the internal dose of radiation from radioactive materials that have accumulated in the body.

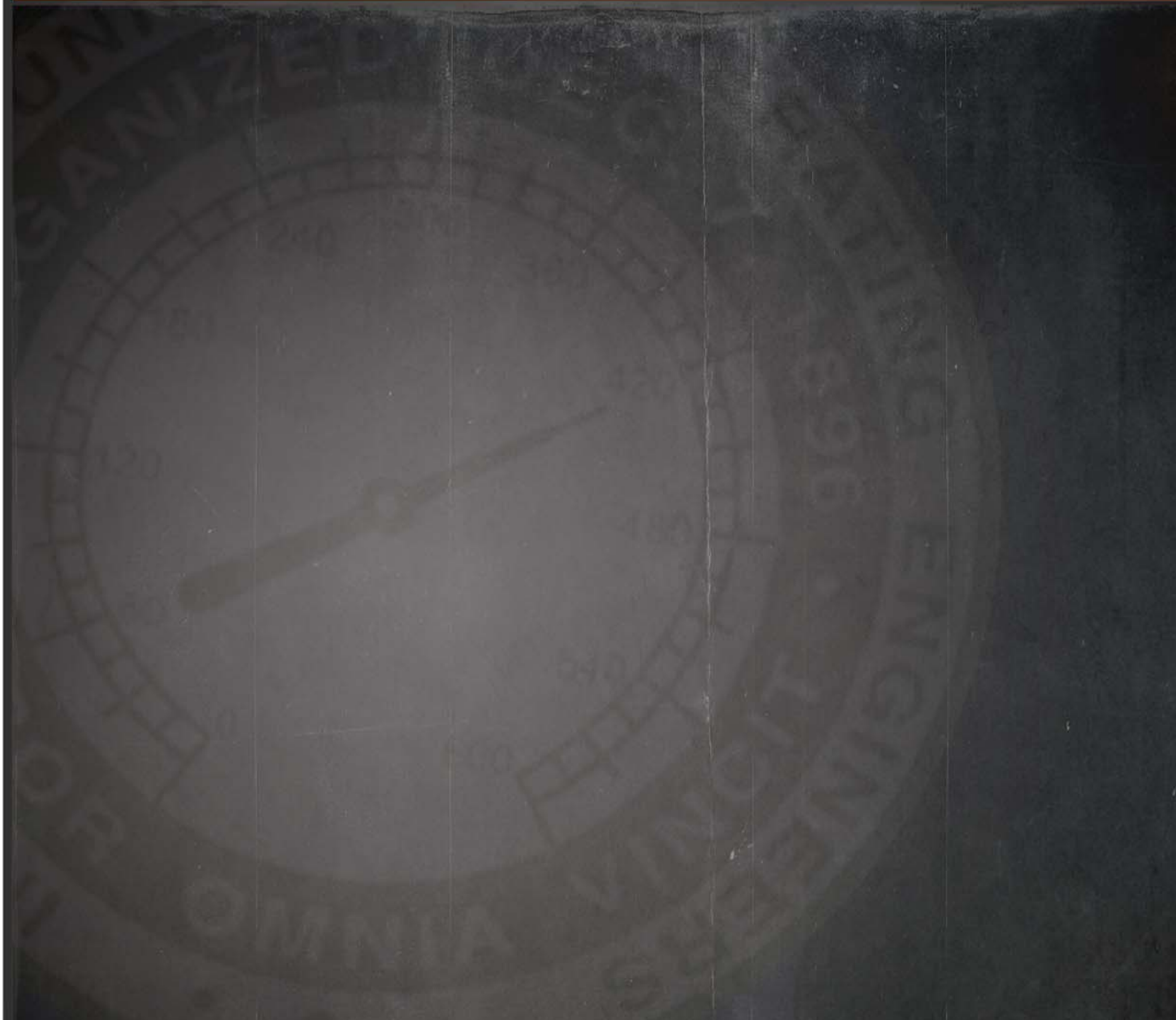
Whole body dose: The sum of the radiation dose equivalent from both internal and external radiation exposures.

Abbreviations and Acronyms

ACL	Administrative control level
ALARA	As low as reasonably achievable
ALI	Annual limit of intake
ARM	Area radiation monitor
Bq	Becquerel
CAM	Continuous air monitor
Ci	Curie
cpm	Counts per minute
DAC	Derived air concentration
DNA	Deoxyribonucleic acid
DOE	Department of Energy
DRD	Direct reading dosimeter
dpm	Disintegrations per minute
dps	Disintegrations per second
EPA	Environmental Protection Agency
Gy	Gray
HEPA	High efficiency particulate air filter
HP	Health physics; health physicist
IBT	International Brotherhood of Teamsters
ICRP	International Commission on Radiological Protection
mR	Milliroentgen (one one-thousandth (1/1000) of a Roentgen.)
mrem	Millirem (one one-thousandth (1/1000) of a rem.)
NCR	Nuclear Regulatory Commission
OSHA	Occupational Safety and Health Administration
PADI	Pocket alarm dose indicator
PIC	Pocket ionization chamber
QF	Quality Factor
R	Roentgen
rad	Radiation absorbed dose
RAM	Radiation area monitor
RBA	Radiological buffer area
RCM	DOE Radiological Control Manual
rem	Roentgen equivalent man
RWP	Radiological work permit
SOP	Standard operating procedure
SRPD	Self reading pocket dosimeter

Sv	Sievert
TEDE	Total effective dose equivalent
TLD	Thermoluminescent dosimeter
μCi	Microcurie (One one-millionth (1/1,000,000) of a Curie.)

RADIOLOGICAL WORKER II COURSE



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